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PB-298 134

Holston River Study

(U.S.) Environmental Protection Agency, Athens, GA

Oct 78

pg. 96

United States
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Region 4
345 Courtland Street, NE
Atlanta GA 30308

EPA 904/9-78-019
OCTOBER 1978

PB 298134

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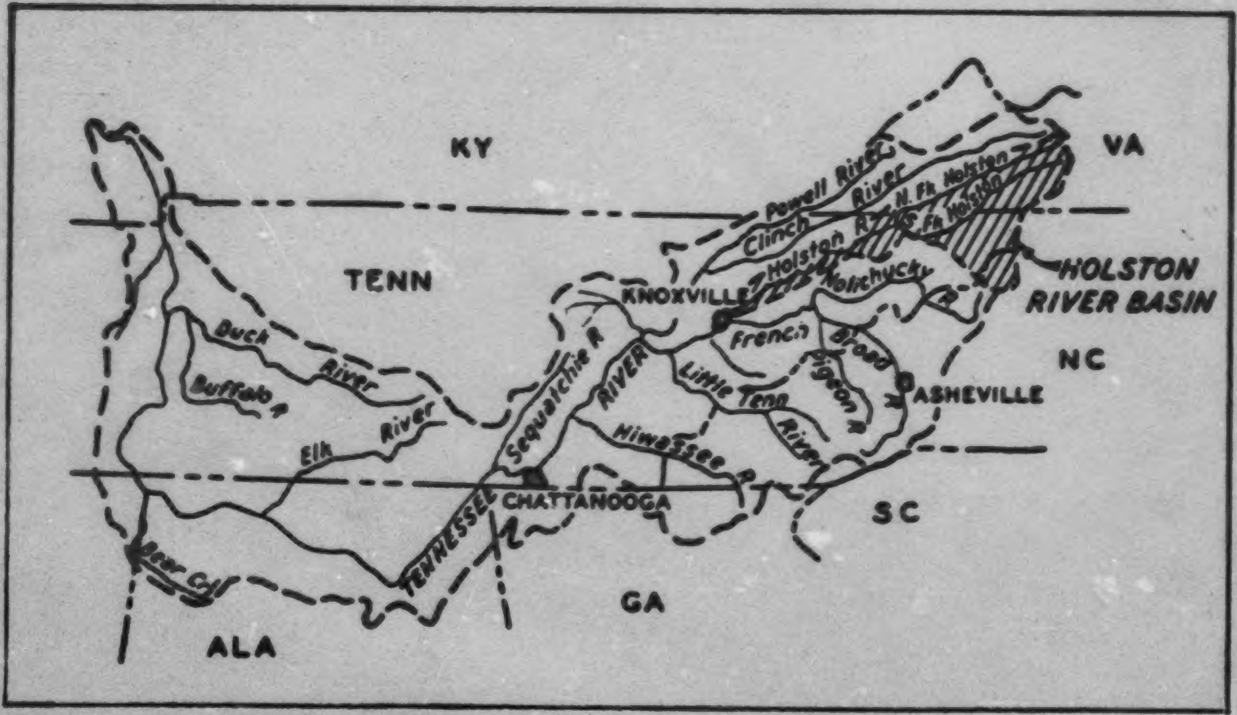
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50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO.
904/9-78-019

2.

3. Recipient's Accession No.
PB298134

4. Title and Subtitle
Holston River Study (Summary Document)

5. Report Date
October 1978

6.

7. Author(s)
R. L. Raschke, editor

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
EPA, Surveillance & Analysis Division
College Station Road
Athens, GA 30605

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) N.A.
(G)

12. Sponsoring Organization Name and Address
EPA, Surveillance & Analysis Division
College Station Road
Athens, GA 30605

13. Type of Report & Period Covered
Intensive Survey

14.
EPA 904/9-78-019

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Biological and water quality studies were conducted on the Holston River and Cherokee Lake Tennessee as part of an evaluation of clean-up efforts in and around Kingsport, Tennessee. Study results showed that water quality in the Holston River had improved considerably. Further downstream in Cherokee Reservoir, trophic conditions had improved, but the data showed that the Lake still had a high potential for algal blooms.

17. Document Analysis a. Descriptors

Water quality, macrophytes, invertebrates, trophic condition, nutrients, phosphorus, nitrogen, benthic oxygen demand, productivity.

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement
Release to public

19. Security Class (This Report)
Unclassified

20. Security Class (This Page)

21. No. of Pages
210

22. Price
PC A10 / MF A01

(See ANSI-Z39.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

HOLSTON RIVER STUDY

July 1978

Environmental Protection Agency
Surveillance and Analysis Division
Athens, Georgia

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ACKNOWLEDGEMENTS

The planning and operation of these studies were conducted under the direction of J. H. Finger, Director, Surveillance and Analysis Division (S&AD) located in Athens, Georgia and two S&AD Branch Chiefs, L. B. Tebo and M. R. Carter of the Ecology Branch and Water Surveillance Branch, respectively.

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SUMMARY

Biological and water quality studies were conducted on the South and North Forks and main-stem Holston River during the summer of 1977. These studies were conducted at the request of Region IV's Enforcement Division to aid them in evaluating proposed NPDES revisions in relation to clean-up efforts along the Holston River system. The major findings are:

- The Tennessee Eastman Company (TEC), The City of Kingsport WTP, and Holliston Mills wastewater discharges exceeded NPDES permit limitations--The Tennessee Eastman effluent exceeded the average daily phosphorus limit; The Kingsport WTP exceeded the monthly average 5-day biochemical oxygen demand (BOD_5) and ammonia (NH_3) limits; Holliston Mills exceeded the daily maximum BOD_5 and Total Kjeldahl nitrogen (TKN) limits.

- Between 1969 and 1977, loadings of BOD_5 discharged into the Holston River system decreased 90 percent (from 137,500 lb/day to 12,700 lb/day); wastewater loadings of total nitrogen decreased about 80 percent (from 21,900 lb/day to 3,700 lb/day); total phosphorous loadings decreased about 50 percent (from 2,000 lb/day to 1,050 lb/day).

- In 1977, 60 percent of the BOD_5 was contributed by Mead Paper Corporation and Holston Army Ammunition Plant's (HAAP) Area A; fifty-five percent of the nitrogen was contributed by Tennessee Eastman and HAAP's Area B; 83 percent of the phosphorous was contributed by Tennessee Eastman and Kingsport's WTP.

- Reductions in industrial and municipal nutrient loading to the South Fork and main-stem Holston River were evident in the improved water quality. There were substantial decreases between 1969 and 1977 levels of BOD_5 and nitrogen. Consequently, the dissolved oxygen (DO) conditions in the Holston River have improved considerably.

- Extensive growths of the alga, Cladophora, observed in 1969, were diminished in 1977.
- A comparison of aquatic plant cover in the mouths (lower 4.5 mile stretches) of the North and South Forks showed that aquatic plant cover was similar in the North Fork, unaffected by point-source pollution from Kingsport, and the South Fork.
- Aquatic plant biomass in the study area was moderate to low when compared to other aquatic systems.
- The QUAL II model simulations indicate that dissolved oxygen levels slightly less than 5.0 mg/L can be maintained in the Holston River during summer months under conditions of low photosynthetic oxygen production and present wastewater discharge loadings. Approximately half the dissolved oxygen deficit can be attributed to rooted aquatic plants. Ammonia-nitrogen discharges have only a small effect on the oxygen balance.

- The North Fork, South Fork, and main stem of the Holston River study area support a diverse and productive aquatic biota. There has been a considerable improvement in the water quality of the Holston River since 1965-1969 but the lower South Fork and main-stem Holston River are still being affected by Ft. Patrick Henry reservoir and dischargers in and around Kingsport as evidenced by some of the species differences between the North Fork and other river segments.

- Luxuriant amounts (those nutrient percent concentrations of aquatic plant dry weight in excess of the minimum amount necessary for maximum growth) of nitrogen and phosphorus are available for aquatic plant growth.

- Phosphorus concentrations in the Holston River are considerably greater than the 50 ug/L level recommended by EPA for streams discharging into lakes or reservoirs.

- The Cherokee Reservoir trophic index value increased from 162 to 363 in a four-year period indicating an improvement in the Reservoir's trophic condition.
- The relatively small amount of growth in the algal assay studies indicated that toxic compounds sufficient to inhibit algal growth may be present in Cherokee Reservoir waters.

CONCLUSIONS

Model simulations show that dissolved oxygen levels at or slightly below 5.0 mg/L can be expected under minimal light conditions and with present wastewater loadings. The 5-day biochemical oxygen demand (BOD_5) and aquatic plant oxygen demands are approximately equal. BOD_5 is a more important consideration in the upper stretch of the Holston River while plant respiration in the lower stretch is more important. The oxygen demand from ammonia-nitrogen oxidation is very small in the reach of the Holston River downstream from Kingsport, Tennessee.

Water quality in the Holston River has improved considerably since 1969. The diverse biota and relatively low standing crop of aquatic plants are evidences of this improvement. Further downstream in Cherokee Reservoir trophic condition had improved since 1973 as a result of clean-up efforts in Kingsport, Tennessee.

1. INTRODUCTION

The Holston River Basin has received widespread attention from state and federal personnel for the past several decades because of numerous pollution problems within its boundaries. Most problems were attributed to industrialization. By the 1930's a number of major industries had located along the Holston, especially in Kingsport, Tennessee. Concomitant with increased industrialization and growth, water quality degradation occurred to such an extent that by the late 1930's water downstream of Kingsport was unfit for most uses (EPA, 1969b).

Increasing waste discharges eventually stimulated aquatic plant growth to the point where extensive nuisance weed beds reduced dissolved oxygen below minimum limits required to sustain a "healthy" biota, and weed die-off clogged intakes. These nuisance weed beds were known to occur in the 1950's (Peltier and Welch, 1969).

Not until the 1960's and 1970's was there a concerted effort to pinpoint problems and deal with them in a critical manner (EPA, 1960 and 1962, 1967, 1969b, 1972, 1973c and d; Nicholas and Gordon, 1973; USFWQA, 1970; Taylor, 1971; Peltier and Welch, 1969; Higgins, 1977; TVA, 1976). Much of the effort was initiated in anticipation of and passage of PL 92-500 in 1972 which required NPDES permits for all point source dischargers.

In the six years since PL 92-500 was enacted and in the interim period NPDES permits have been issued requiring, for many Holston Basin industries and municipalities, improved waste water treatment. Most of the permittees have complied with permit conditions, and EPA is in the process of re-evaluating permits and assessing the effects of clean-up efforts aimed at restoring and maintaining chemical, physical and biological integrity of Holston River waters, especially downstream of Kingsport, Tennessee.

As a prerequisite to the above determinations, it was necessary for the Surveillance and Analysis Division of EPA Region IV to conduct studies for the Enforcement Division. These studies were conducted to:

- Assess the suitability of the North Fork, South Fork, and main stem of the Holston River to support a diverse aquatic biota.

- Determine the waste assimilative capacity and oxygen relationships in the Holston River with special emphasis on aquatic plant effects.

- Determine the extent water quality standards are being met after installation of treatment systems required by July 1, 1977.

- Evaluate the effects of Kingsport clean-up efforts on Cherokee Reservoir trophic condition.

2. STUDY AREA

The Holston River Basin is located in southwestern Virginia and northeast Tennessee (Figure 2.1). The North Fork Holston River originates in southwestern Virginia and flows for about 100 miles in a southwesterly direction crossing the Virginia-Tennessee State line five miles upstream of its confluence with the South Fork Holston River. The South Fork originates on the northwest slopes of The Iron Mountains of southwest Virginia. It flows in a southwesterly direction into Tennessee to its confluence with the Watauga River, its principal tributary. From there, it flows northwesterly through Kingsport, Tennessee, where it joins with the North Fork to form the main stem of the Holston River.

River gradient (Figure 2.2) in the Holston varies from approximately 0.6 meters/km (3.2 feet/mile) on the main-stem Holston between Cherokee Reservoir and Kingsport to 1.6 meters/km (8.3 feet/mile) on the South Fork. The North Fork gradient of 1.2 meters/km (6.2 feet/mile) is slightly less than the South Fork.

The North Fork is free of major dams. Reservoirs controlling flow of the South Fork include: Fort Patrick Henry Reservoir, Boone Reservoir, and South Holston Reservoir.

Cherokee Reservoir impounds about one-third of the length of the main stem Holston River and controls its flow at the French Broad River confluence. Maximum storage volume of the reservoir at full pool elevation is 1,900.824 x 10^6 m^3 (1.54 x 10^6 acre feet) with a mean elevation above sea level of 329.7 meters (1081.7 feet), a maximum depth of 49.7 meters (163.1 feet) and a retention time of 178 days (EPA, 1976a). Its headwaters extend from 30-54 river miles upstream of Cherokee dam, depending on lake surface elevation. Average annual lake discharge is approximately 126.87 m^3/sec (4480 cfs) (TVA, 1977).

The Holston River accounted for about 88% (412,485 kg/yr or 909,529 lbs/yr) of the total phosphorus and about 89% (6,074,340 kg/yr or 13,393,919 lbs/yr) of the total nitrogen entering Cherokee Reservoir (EPA, 1976a). Most of these nutrients were from industrial and municipal sources near Kingsport, Tennessee (EPA, 1976a).

Principal cities along the South Fork include Bristol, Virginia; Bristol, Johnson City, Elizabethton and Kingsport, Tennessee.

Further downstream along the main-stem Holston River are the cities of Morristown, and Knoxville, Tennessee. The largest population center in the area under consideration is Kingsport, Tennessee with 33,860 people.

3. WASTE WATER DISCHARGES AND WATER QUALITY

Most of the major wastewater dischargers are located within and just downstream of Kingsport, Tennessee (Figure 3.1). These dischargers are Tennessee Eastman Corporation, Mead Paper Company, The City of Kingsport's Wastewater Treatment Plant (WTP), and Holston Army Ammunition Plant Areas A and B (Figure 3.1). Further downstream at Holston River Mile (HRM) 128.4 is the Holliston Mills discharge. The John Sevier Steam Plant of the Tennessee Valley Authority (TVA) uses the Holston River as a source of cooling water at HRM 106.5 just upstream from Cherokee Reservoir (Figure 2.1).

The dissolved oxygen standard for the entire Holston River system is 5.0 mg/L because of its classification as suitable for fish and aquatic life (Appendix C). EPA July 1977 NPDES permit limits were based on a 92% reduction of 1969 untreated BOD_5 and ammonia discharge levels in an effort to meet the 5.0 mg/L DO standard (Barnwell, 1976).

4. FLOW REGULATION

Flow of the main-stem Holston River is primarily controlled by regulated flow from Ft. Patrick Henry Dam on the South Fork, and by unregulated flow from the North Fork. Water is released from Ft. Patrick Henry Dam in accordance with an agreement between the Tennessee Eastman Company and TVA which stipulates a minimum daily average flow of 21.2 m^3/sec (750 cfs) for the South Fork. Based on USGS flow records, bihourly flows in the Holston River at Surgoinsville vary from a minimum of 23.8 m^3/sec (840 cfs) in October and December to a maximum of 1209.1 m^3/sec (42,700 cfs) in March. The minimum instantaneous stream flow encountered in applicable historical flow records is 21.0 m^3/sec (742 cfs).

5. RESULTS

5.1 Wastewater Dischargers

The five facilities in the study area which have significant wastewater discharges are Tennessee Eastman Corporation (a major chemicals, fibers, and plastics manufacturer), Mead Paper Company (a partially integrated bleached soda pulp and paper mill), the City of Kingsport's wastewater treatment plant (a 7 mgd trickling filter system), Holliston Mills (a paper and textile manufacturer for book-binding and associated trades), and the Holston Army Ammunition Plant (manufacturer of military explosives). Figure 3.1 shows the locations of these dischargers.

Outfalls at each facility were sampled on a 24-hour composite basis for either three or four days during the period July 19-23, 1977. At least one of the 24-hour composite samples collected at each facility was used for long term biochemical oxygen demand (BOD) analyses. This information was subsequently used in the QUAL II water quality model. Investigation reports for each facility are contained in

Appendix B, and sampling methodology and longterm BOD results are given in Appendix A.

Tennessee Eastman Corporation, the City of Kingsport, and Holliston Mills wastewater discharges exceeded existing NPDES permit limitations during the study period. Tennessee Eastman exceeded the average daily load limitation for total phosphorus; the Kingsport WTP exceeded the monthly average limitations for five-day biochemical oxygen demand (BOD_5) and total kjeldahl nitrogen limitations. Table 5.1-1 summarizes the total wastewater loads for the five facilities. Table 5.1-2 summarizes net concentrations and loads, i.e., effluent less raw water concentrations.

A comparison of waste loadings from the five facilities in 1969 and 1977 are shown in Table 5.1-3. The BOD_5 loads to the Holston River decreased about 90 percent between 1969 and 1977; total nitrogen and phosphorus decreased about 80 and 50 percent, respectively. Tennessee Eastman Corporation, which contributed greater than 50 percent of each of these loads in 1969, now contributes only 18 percent of the BOD_5 and 32 percent of the total nitrogen. Their total phosphorus contribution decreased from 88 percent to 52 percent. These reductions are probably due to their new wastewater treatment system.

In 1977, 60 percent of the BOD_5 was contributed by Mead Paper and Holston Army Ammunition Plant's Area B. Fifty-five percent of the nitrogen was contributed by Tennessee Eastman and HAAP Area B. Eighty-three percent of the phosphorus was contributed by Tennessee Eastman and Kingsport's wastewater treatment plant (Table 5.1-3).

Because of the cessation of the Viet Nam War, there were substantial reductions in BOD_5 loading at HAAP. The total BOD_5 discharged in 1969 from Areas A and B was 25,261 kg/day (55,700 lb/day); in 1977 it was 1805 kg/day (3,980 lb/day) (Table 5.1-3). However, only Area B's total nitrogen load was reduced over the same period of time from 2494 kg/day (5,500 lb/day) to 426 kg/day (940 lb/day). The total nitrogen discharge from Area A and the total phosphorus load from areas A and B increased over the 1969 loadings.

5.2 Water Quality

In order to describe the movement and physical-chemical reactions of a slug of river water as it passed through the study area, Rhodamin-B dye was released at South Fork Holston River Mile (SFHRM) 1.2. As the dye peak moved past each water quality sampling station a grab sample for biochemical oxygen demand (BOD), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3), nitrite-nitrate nitrogen (NO_2-NO_3), total phosphorus (TP), dissolved oxygen (DO), pH and temperature analyses were collected by field personnel. Additional samples were collected at each station at six, twelve and twenty-four hours after passage of the tracked slug of water (dye peak). Results of these analyses including long term BOD, with and without suppressed nitrification, are given in Appendix A.

Average BOD_5, TP, and total nitrogen (TN)) concentrations for each station (Figure 5.2-1) increased between Stations SFHRM 1.2 and the first water quality sampling station downstream of all Kingsport wastewater dischargers (HRM 136.2). Average BOD_5, TP and TN concentrations in this reach (SFHRM 1.2 to HRM 136.2) were 147, 1,750, and 247 percent, respectively of background at SFHRM 5.6 and average concentrations were 183, 2,333, and 495 percent respectively of these pollutants as measured at the background water quality station [North Fork Holston River Mile (NFHRM 0.6)]. The various nitrogen forms as illustrated in Figure 5.2-2 show that nitrification was taking place throughout the downstream reaches beginning at HRM 139.2.

Because of aquatic plant growth in the Holston River, the DO data base (four or less samples in a 24-hour period at each station (Figure 5.2-3) did not accurately reflect diel DO conditions in the Holston River. At selected river sampling stations diel DO data were collected more frequently. These data are presented in the community and benthic metabolism sections.

Based on the DO samples collected at the dye peak as well as six, twelve and twenty-four hours thereafter; average DO values (Figure 5.2-3) were less than 5.0 mg/L only at Station HRM 141.3. At this station the average DO was 4.9 mg/L. Minimum DO levels of 3.4 and 3.9 mg/L were recorded at Stations SFHRM 1.2 and HRM 136.2, respectively. Overall trends from this DO data base reveal DO sags downstream of the Kingsport area and also downstream of HAAP Area B, with recovery in the middle reach of the study segment. A DO sag downstream of Holliston Mills followed by recovery in the final stream reaches at HRM 118.4 was also observed.

The temperature profile (Figure 5.2-4) shows a rapid rise in temperature downstream of SFHRM 5.6 and a relatively uniform profile for the remainder of the study segment.

Temperature and DO measurements were conducted on a mid-depth cross sectional basis on July 21 (river water quality measurements commenced on July 23) at HRM 141.3 and HRM 140.5 in order to describe the mixing of the North and South Forks of the Holston River. These measurements (Figure 5.2-5) reveal a non-uniform condition at HRM 141.3 with improved mixing at HRM 140.5. After a noticeable but moderate rise in water stage, the mixing inequalities on the left bank at Station HRM 140.5 were negated.

The data base and river flows for the 1969 (EPA, 1972) and 1977 EPA studies are very similar. There were substantial decreases between 1969 and 1977 levels of BOD_5 and nitrogen (Figures 5.2-6 and 5.2-7). Similarly, the DO conditions in the Holston River have improved considerably in the 8-year period (Figure 5.2-8).

5.3 Macroinvertebrates and Periphyton

Diversity indices, specifically mean diversity ($\bar{d}$) and equitability (e), were derived from artificial substrate samples collected on all Holston River stations. Mean diversity as computed by the Lloyd, Zar and Karr formula discussed in the Biological Field and Laboratory Methods Manual (EPA, 1973a), is affected by both richness of species and distribution of individuals among the species. Some workers have found that mean diversity in unpolluted waters was generally between 3 and 4, whereas in polluted waters ($\bar{d}$) was below 1 (EPA, 1973a). Equitability, a measure of distribution of individuals among the species, was computed by the method of Lloyd and Ghelardi as outlined in the Biological Field and Laboratory Methods Manual (EPA, 1973a). Where ($\bar{d}$) often lacks the sensitivity to demonstrate differences, equitability has been found to be very sensitive to even slight levels of degradation. Generally, values below 0.5 are indicative of stress.

The station for invertebrate sampling on the North Fork (NFHRM 4.2) was located in Tennessee approximately one-quarter mile south of the Virginia-Tennessee state line. The river width at this station was approximately 31 meters with an average bottom depth of about forty-six centimeters. The river bottom was primarily bedrock, interspersed with rock and rubble. Very small amounts of silt and sand were present in the rock crevices and small pools at the station. A dense assemblage of macrophytes, mainly *Heteranthera dubia*, *Potamogeton pectinatus*, and *Potamogeton nodosus*, were found at this station. Smaller beds of *Anacharis canadensis* (Elodea) and *Vallisneria americana* were also present.

Invertebrate collections, both qualitative and quantitative, from North Fork station NFHRM 4.2 resulted in greater numbers of taxa than occurred at stations on the South Fork Holston River or Holston River (Figure 5.3-1, Appendix A. Table A-3.1). The numbers of taxa and individuals at NFHRM 4.2, however, were not significantly different from numbers at stations on the South Fork Holston River or Holston River (Tables 5.3-1 and 5.3-2). A total of 40 invertebrate species were collected by the qualitative method and 33 species of invertebrates were collected by the quantitative sampling method. Midges (Diptera: Chironomidae), Mayflies (Ephemeroptera), and beetles (Coleoptera) were the main constituents represented in collections from NFHRM 4.2. The snail *Goniobasis* was the most abundant individual species found at NFHRM 4.2. In contrast to the other Holston River stations there were five invertebrate species present at NFHRM 4.2, *Neureclipsis crepuscularis*, *Helicopsyche* sp., *Psephenus* sp., Stenonema exiguum, and Cladotanytarsus sp. (Appendix A, Table A-3.1); these are considered "clean water" indicators (EPA, 1973). These intolerant species are not found associated with even moderate levels of organic contaminants and are generally intolerant of even moderate reductions in dissolved oxygen (EPA, 1973). Mean diversity ($\bar{d}$) for the individual cone samplers at NFHRM 4.2 ranged from 1.47 to 3.08 (Table 5.3-3. The low ($\bar{d}$) value (1.47) is attributable to the predominance of the snail Goniobasis sp. which composed 154 of the 199 specimens collected in that replicate sample (Appendix A, A-3.1). Equitability was also affected by the predominance of Goniobasis sp. in this same replicate. The ($\bar{d}$) values at NFHRM 4.2 were not significantly different from values at stations on the South Fork Holston River or Holston River (Table 5.3-4). Equitability values at NFHRM 4.2 ranged from 0.27 to 0.63 (Table 5.3-3).

Two invertebrate sampling stations were located on the South Fork, one upstream of the retention dam at the Tennessee Eastman Company at SFHRM 5.75 and the other approximately 137 meters downstream of the Ridgefield Bridge near SFHRM 1.2.

The river width at the station on the South Fork Holston River at SFHRM 5.75 was approximately 61 meters with an average bottom depth of approximately 1-2 meters. The river is impounded by the Fort Patrick Henry Dam upstream of the station (near SFHRM 8) and the retention dam downstream of the station (near SFHRM 4.5). Bottom substrate at SFHRM 5.75 was a mixture of sand and silt. Aquatic vegetation was not observed at SFHRM 5.75.

Invertebrates were not sampled qualitatively at SFHRM 5.75 but quantitative samples were obtained from the artificial substrate samplers. Midges (Diptera: Chironomidae) predominated in the samples representing 76% of species of invertebrates collected (Appendix A, Table A-3.1). This predominance of the Chironomids is understandable since many of the stream dwellers such as Ephemeroptera, Odonata and Trichoptera were not as abundant possibly due to the fluctuation in flow, in this impounded station. The midge fauna at SFHRM 5.75 was represented by species present in both lacustrine or riverine habitats: *Nanocladius distinctus*, *Cricotopus bicinctus*, *Rheotonytarsus* sp. There were no snails present in collections from SFHRM 5.75. The absence of snails at SFHRM 5.75 can most likely be related to the lack of aquatic plants (a detrital source) or the interrupted flow characteristics of this station. The cladoceran *Sida crystallina* was abundant in the artificial substrate samples but was not considered a member of the benthic fauna. Mean diversity ($\bar{d}$) values were not significantly lower at SFHRM 5.75 than the other South Fork station (SFHRM 1.2) (Table 5.3-3 and Table 5.3-4). Numbers of taxa and individuals from SFHRM 5.75 were not significantly different from other Holston River stations (Tables 5.3-2 and 5.3-3). Many groups such as Crustacea, Ephemeroptera, and Trichoptera were not represented at SFHRM 5.75 with as many species as were found at the other Holston River stations (Appendix A, Table A-3.1). This fact, plus numerical predominance by 3 midge species, offers an explanation for lower species diversity (Table 5.3-3). Fewer predators and finer sediments for case-building were probably attributable to predominance by these midge species. Equitability values ranged from 0.2 to 0.5 (Table 5.3-3) at SFHRM 5.75.

The invertebrate station at the Ridgefield Bridge (SFHRM 1.2) was located in a stretch of river approximately 91 meters wide with an average bottom depth of 46 centimeters. Except for some small sedimented pools, the bottom substrate at SFHRM 1.2 was mainly rocky rubble and sand. Several large beds of Potamogeton pectinatus and smaller beds of Potamogeton nodosus were present at the station.

The invertebrate population at SFHRM 1.2 was sampled both quantitatively and qualitatively. Midge abundance in the artificial substrate samples was similar to that at SFHRM 5.75 comprising 63% of the species composition (Appendix A, Table A-3.1). Conchapelopia sp., Nanocladius distinctus, Cricotopus bicinctus, Cricotopus slossonae, and Polypedilum illinoense were the most abundant midge species present at SFHRM 1.2. There were originally four artificial substrate samplers set out at SFHRM 1.2, two upstream of the bridge and two downstream of the bridge. Only the two samplers located downstream of the bridge were retrieved. These samplers were being affected by water from the sluice utilized by the industries located on Long Island. The missing samplers were located in the main stem of the river upstream of the entry point of the sluice water. Biologists qualitatively sampling the area near the missing artificial substrate samplers reported seeing a greater assemblage of organisms in this area as opposed to the side influenced by the sluice.

The number of taxa increased from 24 species in the artificial substrate samples to 45 species when qualitative sampling was included in the species total (Appendix A, Table A-3.1). This result is also a reflection of the two different habitats (main stem river and sluice water affected reach) evident at SFHRM 1.2.

Mean diversity ($\bar{d}$) values for the two artificial substrate samplers at SFHRM 1.2 were 3.39 and 2.64 (Table 5.3-3). The diverse invertebrate and midge fauna plus a lack of numerical predominance by two or three species are responsible for the high values. Equitability values were also high at SFHRM 1.2 (Table 5.3-3). Both ($\bar{d}$) values and numbers of taxa and individuals were not significantly different from those found at other Holston River stations (Table 5.3-4).

Two invertebrate sampling stations were located on the main stem of the Holston River, one at Smiths Bend (HRM 134) and the other at Phipps Bend (HRM 122.8).

River width at Smiths Bend (HRM 134) was approximately 91 meters with an average bottom depth of 56 centimeters. A large moss bed, composed of Fissidens fontanus and Leptodictyum riparium, was located on the left side (looking upstream). The mosses were attached to boulders and rocky rubble in the streambed. Smaller beds of *Potamogeton nodosus* and *Potamogeton pectinatus* were present on the right side. The river bottom on the right side did not have as much exposed bedrock as the left side. There were large amounts of rock and rubble with some pools collecting sand and silt.

Qualitative and quantitative sample collections were made at Smith Bend. Midges were the predominant group at Smith Bend in both quantitative and qualitative samples (Appendix A, Table A-3.1). *Cricotopus exilis* and *Conchapelopia* sp. were the most common midges at Smith Bend. An increase in mollusk fauna occurred at Smith Bend when compared with numbers collected at Station SFHRM 1.2 (Appendix A, Table A-3.1). An increase in species of Odonata was evidenced in the qualitative samples as compared to qualitative samples at SFHRM 1.2. Artificial substrate samplers on the right side of the river (looking upstream) were lost. Diversity ($\bar{d}$) values (Table 5.3-3) from the two artificial substrate samplers retrieved were 3.48 and 3.05. Though ($\bar{d}$) values increased at Smith Bend from ($\bar{d}$) values at the North and South Fork stations, the increase was not significant (Table 5.3-4). Equitability values of 0.89 and 0.79 at Smith Bend corresponded with the higher ($\bar{d}$) values. A total of 19 species was found in artificial substrate samples (Appendix A, Table A-3.1) and 37 species in qualitative sampling (Appendix A, Table A-3.1). Numbers of taxa and individuals present at Smith Bend proved to be not significantly different from other Holston River stations (Tables 5.3-1 and 5.3-2).

The river at Phipps Bend was approximately 122 meters wide with an average bottom depth of 75 centimeters. Luxuriant plant beds of *Vallisneria americana* and *Potamogeton nodusus*, and mixed beds of *Heteranthera dubia*, *Vallisneria americana*, and *Potamogeton pectinatus* were present at Phipps Bend. Bottom characteristics at Phipps Bend were similar to Smith Bend.

Invertebrates were sampled qualitatively and quantitatively at Phipps Bend. A total of 29 and 37 species was collected by quantitative and qualitative means respectively (Appendix A, Table A-3.1). Numbers of taxa and individuals collected at Phipps Bend were not significantly different from those collected at other Holston River stations (Tables 5.3-1 and 5.3-2). The midges were the most abundant group of invertebrates in the samples. *Conchapelopia* sp., *Cricotopus bicinctus*, and *Polypedilum* nr. *illinoense* were the most abundant midge species at Phipps Bend (Appendix A, Table A-3.1). Caddisflies (Trichoptera) were the second most abundant group at Phipps Bend with predominant species being *Cheumatopsyche* sp., and *Hydropsyche bifida* group (Appendix A, Table A-3.1). Numerical abundance was dominated by a mayfly (*Stenonema interpunctatum* group) and a snail (*Goniobasis* sp.) (Appendix A, Table A-3.1). Diversity values ranged from 1.09 to 3.07 (Table 5.3-3). The ($\bar{d}$) values at Phipps Bend were lower than some of the other stations and probably reflect the numerical dominance by *Stenonema interpunctatum* and *Goniobasis* sp. (Appendix A, Table A-3.1). Equitability values at Phipps Bend ranged from 0.17 to 0.69 (Table 5.3-3).

The periphyton community is an excellent water quality indicator because it reflects the quality of water continuously flowing over it. Community changes may range from slight alterations to extreme shifts in composition especially when the community is altered to predominantly slime forming bacterial colonies by the addition of municipal organics. One means of determining changes is through the Autotrophic Index (AI) which is the ratio of organic biomass (ash-free-dry weight) to chlorophyll *a*:

$$\frac{\text{AFDW in g/m}^2}{\text{chlorophyll } \underline{a} \text{ in g/m}^2} = \text{AI}$$

Where: periphyton ash-free-dry weight (AFDW) and chlorophyll a are expressed in g/m^2 of surface from which the sample was removed.

AI values ≤ 100 are indicative of organically unpolluted waters (Weber, 1971). As heterotrophic organisms replace autotrophic organisms, the index value increases. Autotrophic Index values over 1000 indicate moderate pollution (Weber and McFarland, 1969).

Average AI values in 1977 ranging from 37.37 in the North Fork (NFHRM 4.5) to 140.56 at Phipps Bend (HRM 122.8) in the main-stem Holston River (Table 5.3-5) were very low and indicative of waters unpolluted by organic wastes. The AI value at Phipps Bend was significantly greater ($\alpha=.05$) (Table 5.3-6) than other stations. Possibly there was a greater cropping of algae by the snail Goniobasis at Phipps Bend which depressed chlorophyll a values (Table 5.3-5) thus increasing the AI value.

In the treatment of chlorophyll a, the ratio of the chlorophyll a to its degradation product, pheophytin a, can be derived and used as an indicator of physiological condition (Weber, 1971). A ratio of 1.7 indicates the algal community is very healthy while a ratio of 1.0 would indicate an unhealthy or dead community of algae. The mean ratios of chlorophyll a to pheophytin a at the Holston River stations ranged from 1.35 at NFHRM 4.5 to 1.58 at HRM 135.4 in the Holston River (Table 5.3-5). Generally, these ratios indicate a healthy periphytic community.

Chlorophyll a average values ranged from 0.054 g/m^2 at SFHRM 1.2 to 0.142 g/m^2 at NFHRM 4.5 whereas periphyton biomass ranged from 2.88 g/m^2 at SFHRM 1.2 to 8.47 g/m^2 at Phipps Bend (HRM 122.8) (Table 5.3-5). These relatively low values for chlorophyll a and biomass were not surprising because extensive growths of periphyton, especially the filamentous alga *Cladophora*, were not observed during the 1977 sampling.

5.4 Aquatic Plants

From July 21 to July 28, 1977 aquatic plant studies were conducted throughout the Holston River System. Purpose of these studies was to provide information for waste assimilative capacity and oxygen relationship modeling efforts and nutrient budget calculations. Specifically, vegetation studies included an assessment of aquatic plant cover, biomass, nutrient content and a leaf area index (LAI) or "habitat space".

For convenience and comparative purposes, the Holston River was divided into segments. These segments are:

Segment 1 - Holston River Mile (HRM) 109.0 - HRM 141.2 (Interplant Bridge)

Segment 2 - HRM 141.2 - South Fork Holston River Mile (SFHRM) 5.6. That area encompassing Tennessee Eastman's, Mead's and Kingsport STP waste discharges.

Segment 3 - North Fork Holston River Mile (NFHRM) 0.3 (Rotherwood Bridge) - NFHRM 39.1.

Segment 4 - SFHRM 5.6 - SFHRM 8.2 (Ft. Patrick Henry Dam).

Segment 5 - SFHRM8.3 - SFHRM 49.9 (South Holston Dam).

During the study, a considerable amount of vegetation was found in the Holston River System. Predominant species, based on aerial photointerpretation (Appendix D), included Potamogeton pectinatus (Sago Pondweed), Potamogeton nodosus, Heteranthera dubia, Vallisneria americana, Anacharis (Elodea) canadensis; two mosses, Fissidens fontanus and Leptodictyum riparium; and two algae Chara sp. and Nitella sp..

Sago Pondweed was conspicuous throughout the North Fork (Segment 3), lower South Fork (Segment 2) and Holston River proper (Segment 1) whereas Chara, Nitella and Elodea were predominant in the upper South Fork (Segments 4 and 5); that portion upstream of Kingsport, Tennessee. Noticeably absent or at least substantially reduced was the alga Cladophora which was quite in evidence during the 1969 survey (EPA, 1972).

The subsequent exposition will focus primarily on segments 1, 2 and 3. Segments 4 and 5 consist predominantly of Elodea and the two algae, Chara and Nitella. Predominance of these three plant species in reference to aerial photointerpretation (Appendix D) and biomass (AFDW) (Table 5.4-1) appears to be a problem unique to the upper South Fork watershed for two reasons. First, during minimal flows, Chara and Nitella beds, exposed on rock outcrops, emit a musky odor which is displeasing. Secondly, massive amounts of _Chara_ and _Nitella_ float free and eventually clog water intakes (personal communications between EPA, TVA and state personnel). Whether the algal growths result primarily from natural or artifical causes is beyond the scope of this study.

For convenience, Segment 1 will be referred to as the Holston River, Segment 2 as the South Fork, and Segment 3 as the North Fork.

An examination of photointerpretation figures (Appendix D) showed that Sago Pondweed (_Potamogeton pectinatus_) predominated in the South Fork stretch around Kingsport. Extensive stretches of Sago Pondweed were noticeable below Tennessee Eastman Company's dam and where Horse Creek enters the sluice at Long Island. Intermingled with the Sago Pondwood beds were a few patches of _H. dubia_ and _P. nodosus_. Sago Pondweed continued to predominate in the Holston River from HRM 141.2 downstream to Smiths Bend (HRM 134.2) where more patches of moss, _H. dubia_, _V. americana_ and _P. nodosus_ occurred. Plant beds were not too extensive from HRM 141.2 downstream to Smith's Bend. At Phipps Bend a good mixture of vascular plants appeared, but even through the lower stretch of the river Sago Pondweed was predominant and much in evidence. In the North Fork, from its mouth up to the Tennessee-Virginia Border, two species, Sago Pondweed and *P. nodosus*, were predominant but there was a good mix of other plant beds such as *H. dubia*, *V. americana*, *Justicia americana* (Water Willow), and *Chara* and *Nitella*. Further upstream, the predominant plant beds consisted of Sago Pondweed followed by *P. nodosus*, mossbeds, patches of *H. dubia* and Water Willow. No *V. americana*, Elodea, or *Chara* and *Nitella* beds were detected in the Virginia section of the North Fork.

In earlier deliberations with TVA personnel, including modelers, discussions centered around moss beds and there possible importance in the Holston River System. Estimates of moss extent and biomass were made during the 1977 study. Photointerpretation data showed that mossbeds ($\geq$70% moss) were not extensive throughout the Holston River and contained significantly (α.05) less biomass (AFDW) than other plant beds sampled (Table 5.4-2). Even though moss beds were not as extensive as at first believed, the derived data, useful for other purposes, has been incorporated into other sections of this report. The remainder of this section will concentrate primarily on other plant beds which of course may have mosses (≤70%) in them. It is these other plant beds, consisting primarily of Sago Pondweed, P. nodosus, H. dubia and V. americana intermixed in various combinations and with other plant species, that concern us because of the emphasis placed on them in 1969 with respect to waste assimilative capacity, oxygen relationships and nuisance problems.

Percent aquatic plant cover (Table 5.4-3) in segments 1, 2 and 3 ranged from 27.6 in the North Fork (Segment 3) to 68.79 in the South Fork (Segment 2) which includes the Kingsport area. The Holston River (Segment 1) aquatic plant cover was slightly less (67.4%) than the South Fork's, possibly indicating the greater influence of South Fork waters on Holston River plants. South Fork (Segment 2) and Holston River (Segment 1) aquatic plant cover is 2.4 to 2.5 times greater respectively than aquatic plant cover in the North Fork. Upstream of Kingsport (Segments 4 and 5), where Chara, Nitella and Elodea predominate, there is 41.6 to 52.5% plant cover which is up to 1.9 times greater than plant cover in the North Fork. Plant cover in Segment 2 of the South Fork was only 1.3 to 1.6 times greater than plant cover in Segments 4 and 5 of the South Fork. Comparisons of plant cover in unequal stretches of a river can be somewhat misleading; therefore, in an attempt to gain a better perspective of the situation, aquatic plant cover was compared between the North (Segment 3A) and South Forks (Segment 2A) from river miles 0.0 to 4.5 (Table 5.4-3) which amounted to approximately equivalent hectares. When comparing these two stretches of the Forks, plant cover was found to be similar--58.7% in the South Fork and 56.3% for the North Fork (Table 5.4-3). Ash-free-dry-weight was not significantly different (at α .05) (Table 5.4-2) among plant beds sampled in the North and South Fork. Whether or not 50% or more of aquatic plant bed cover is desirable is somewhat arbitrary and dependent on type of nuisance being considered. Fifty to 75% plant cover providing habitat for macroinvertebrates and fish is beneficial in a stream unless plant beds criticaly reduce oxygen at night and stress endemic organisms.

Average chlorophyllous (above "ground" organs like green stems and green leaves) dry weight (DW) in aquatic plant beds ranged from 64.21 g/m^2 at Smiths Bend (HRM 134.2) to 371.38 g/m^2 at Surgoinsville (HRM 117.6) (Table 5.4-1). At the Smiths Bend site where mosses predominated there was only a slight increase in average total DW of 2.45 g/m^2 beyond that found for the chlorophyllous DW (Table 5.4-1). The Surgoinsville beds had the greatest average total DW of 415.54 g/m^2 (Table 5.4-1).

In turn, minimum and maximum AFDW's were found also at the Smiths Bend and Surgoinsville aquatic plant beds, respectively. Average chlorophyllous AFDW ranged from 20.54 g/m^2 at Smiths Bend to 206.25 g/m^2 at Surgoinsville and average total AFDW ranged from 22.52 g/m^2 to 238.34 g/m^2 at the same two beds respectively (Table 5.4-1).

Although there appears to be a trend of increasing average chlorophyllous AFDW progressively downstream, an analysis of variance using Duncan's Multiple Range Test for unplanned comparisons shows there are no significant differences (at α.05) among the beds except at Smiths Bend (Table 5.4-2). Smiths Bend, where mosses predominated, had significantly less average chlorophyllous AFDW than other beds sampled (Table 5.4-1).

Presence of mosses in the Holston River indicates river conditions are improving because moss beds were not reported in the 1969 survey (EPA, 1972) yet, they are not uncommon inhabitants of mountainous streams. The reduction in Cladophora coupled presumably with an increase in moss beds is a beneficial trade-off, at least, in terms of reducing nuisance clogging of intakes.

The 1969 study concentrated on chlorophyllous biomass (AFDW) of the other predominant aquatic plants; therefore, it is pertinent to focus on that aspect for comparative purposes.

Chlorophyllous biomass (AFDW) in the Holston River (Segment 1) was 199.79 metric tons (220.27 short tons) (Table 5.4-4). This amounted to 50 tons more biomass than found in the 1969 study (EPA, 1972). Biomass differences were possibly due to sampling devices used. An orange peel dredge (Figure 5.4-1) was used in the 1969 study during relatively high river flows whereas a 0.25 m^2 P & D sampler (Figure 5.4-2) was used in 1977 during relatively low river flows. The P & D sampler is basically an enclosed version of a Surber sampler whereby personnel wading or diving on plant beds collect vegetation and inspect sampled areas to determine if all plants are harvested. TVA (Emery, 1967) used a sampling device similar to the P and D sampler in 1967 when they sampled for aquatic plants. Extensive plant beds prevailed in the main-stem Holston River at this time (1967-1969) and presumably they were somehwat similar in extent. An examination of average biomass (AFDW) estimates at relatively similar locations in 1967 and 1969 (Table 5.4-6) indicates that EPA in 1969 may have underestimated biomass (AFDW) eleven fold.

The other two segments had considerably less chlorophyllous tonnage (AFDW). The South Fork (Segment 2) at Kingsport had 39.89 metric tons (43.98 short tons) of biomass in a 6.6 mile stretch of river and the North Fork (Segment 3) had 40.88 metric tons (45.07 short tons) of biomass in a 38.8 mile stretch (Table 5.4-4).

Average chlorophyllous biomass (AFDW) for the three segments amounts to 0.40 metric tons/ha (0.18 short tons/acre) for the Holston stretch (Segment 1); 0.58 metric tons/ha (0.26 short tons/acre) for the South Fork stretch (Segment 2); and 0.12 metric tons/ha (0.05 short tons/acre) for the North Fork stretch (Segment 3) (Table 5.4-4). These biomass levels are relatively low compared to other aquatic and terrestrial systems. Although North Fork biomass is 3 to 6 times less than biomass in Segments 1 and 2 and 1.8 times less in an equivalent stretch of the South Fork (Segment 3A vs Segment

2A) (Table 5.4-4), significant differences (Table 5.4-2) among plant beds in the three segments were not detected except where mosses were prevalent.

Average total (entire plant including the subterranean parts) plant biomass (AFDW) followed the same trend where greatest biomass (0.64 metric tons/ha of river) was recorded for the South Fork (Segment 2), slightly less tonnage (0.45 metric tons/ha of river) was determined for the Holston River segment, and 0.13 metric tons/ha of river was calculated for the North Fork (Table 5.4-5).

Aquatic vascular plant nutrient (nitrogen and phosphorus) content was determined primarily for use in the nutrient budget. Average total nitrogen (chlorophyllous plus non-chlorophyllous) in g/kg DW for predominant species ranged from 17.81 (1.78%) in H. dubia to 22.67 (2.27%) in P. pectinatus (Table 5.4-7). The chlorophyllous parts contained more nitrogen than the subterranean plant parts (non-chlorophyllous) as average total chlorophyllous nitrogen in g/kg DW ranged from 20.91 (2.09%) in H. dubia to 24.26 (2.43%) in P. pectinatus whereas the non-chlorophyllous nitrogen ranged from 13.46 g/kg (1.35%) in H. dubia to 19.89 g/kg (1.99%) in P. pectinatus.

Average total phosphorus ranged from 2.01 g/kg DW (0.20%) in P. nodosus to 3.02 g/kg DW (0.30%) in V. americana (Table 5.4-7). Again chlorophyllous total phosphorus was greater than the total phosphorus found in the subterranean or non-chlorophyllous portion of the predominant species (Table 5.4-7). Chlorophyllous phosphorus ranged from 2.12 g/kg DW (0.21%) in P. nodosus to 3.06 g/kg DW (0.31%) in V. americana whereas non-chlorophyllous phosphorous ranged from 1.81 g/kg DW (0.18%) in P. pectinatus to 2.98 g/kg DW (0.30%) in V. americana.

The above phosphorus and nitrogen percentages are in excess of that amount needed for plant growth. The significance of these percentages will be explained in the discussion section of this report. Further examination of plant nutrient data (Table 5.4-8) showed that percent phosphorus content increased in a progressive manner downstream from Kingsport. Presumably, more phosphorus was available for plant uptake because of the natural oxidation of organophosphates.

Holston River average total nitrogen in kg/ha bound by aquatic plants ranged from 11.15 to 86.27 at Smiths Bend location HRM 134.2 and Phipps Bend location HRM 119.7, respectively (Table 5.4-9). Average total nitrogen at the North Fork site was 29.33 kg/ha and in the South Fork (SFHRM 1.2) 46.31 kg/ha.

The North Fork contained 2.92 kg/ha of average total phosphorus whereas 4.62 kg/ha of total phosphorus was calculated for the South Fork (Table 5.4-9). These concentrations amount to 9.59 metric tons of total nitrogen (10.57 short tons) and 1.33 (1.47 short tons) metric tons of total phosphorus bound-up by plants in Segment 1 of the Holston River (Tables 5.4-10 and 5.4-11). Plants in the South and North Forks had bound-up to 1.91 and 1.95 metric tons of nitrogen, respectively, and 0.26 and 0.28 metric tons of total phosphorus at the time of sample collection.

The Leaf Area Index (LAI) is a structural measure providing insight into community and habitat space. Presumably the greater the LAI in m^2/m^2 of bottom surface, the more habitat space there is for the fauna. LAI's calculated for the Holston River ranged from 0.01 m^2/m^2 at Smiths Bend where mosses predominated to 1.05 m^2/m^2 at Phipps Bend (HRM 119.7) where *V. americana* was predominant (Table 5.4-12). Throughout the Holston system the average LAI was 0.37 m^2/m^2 (Table 5.4-12). These values are low when compared to other systems where LAI's may exceed 20 m^2/m^2.

5.5 Nitrogen/Budget

One of the major perturbations inflicted upon the Holston River within the study area is the discharge of various forms of nitrogen into the river by industries in the Kingsport area. The object of the nitrogen budget phase of the study was to determine the fate of this input of nitrogen within the study area.

Since the Holston river under normal operating conditions is subject to intermittent releases from the Ft. Patrick Henry Reservoir, TVA was requested to release water in such a way that a relatively steady state condition would exist in the river during the study period. The study was initiated under such conditions but problems forced early curtailment of the controlled flow and fluctuating conditions prevailed for the remainder of the study. In order to utilize the datum gathered during the study to its fullest extent, it was analyzed in two ways. One analysis used only the 12 hours of steady state condition. The results are referred to in the text, graphs and tables as "steady state condition". The other analysis utilized all 24 hours of data and the results are referred to as "fluctuating flow conditions". Only industrial and municipal inputs and inflows from the two forks of the river were considered as inputs to the system in this study. Hypothetical Station X represents the composites of these inputs.

Tables 5.5-1 and 5.5-2 show the concentrations of TKN, NH_3-N, and NO_2-NO_3 at various stations in the river during steady state and fluctuating conditions. Figures 5.5-1, 5.5-2, 5.5-3 and 5.5-4 show the same data in graph form compared to a hypothetical station X. The concentrations of the varous forms of nitrogen for station X were calculated by adding the loading from the South Fork and North Fork Holston River.

The nitrogen data shows that under fluctuating flow conditions all forms of nitrogen increased significantly between station X at the upstream edge of the study area and Station 120 located at the downstream edge. Under the steady state condition nitrite-nitrate concentrations increased significantly, kjeldahl nitrogen decreased significantly and ammonia nitrogen was not significantly different at the .05 probability level (Table 5.5-3). Both TKN and NH_3-N were greater at the downstream stations than at midstream stations.

Figures 5.5-5, 5.5-6, 5.5-7 and 5.5-8 show the difference in lbs/hour between upstream station X and downstream stations. The zero line in the figures represents station X. The area below the zero line represents negative values and area above the line represents positive values.

Under steady state condition TKN loading was always less than station X in the downstream stations. However, the loading at the downstream station was greater than it was in the middle station. NH_3-N loading was less than station X at the first two downstream stations. Nitrite-Nitrate loading was less than station X at the first downstream station but increased and was greater than station X at the second downstream station.

Under the fluctuating flow condition, TKN and NH_3-N was greater than station X at all downstream stations. Nitrite-nitrate ammonia loading was slightly less than station X at the first downstream station but then increased and was greater than station X at the remaining downstream stations.

Total nitrogen followed the pattern set by nitrite-nitrate nitrogen in both the steady state and fluctuating condition; but, of course, it was present in higher concentrations (Figure 5.5-5).

5.6 Phosphorus Budget

Phosphorus concentration (Table 5.5-4) in both the North (NFHRM 0.6), and South (SFHRM 7.2) Forks were similar (0.04 mg/L total phosphorus, 0.02 mg/L dissolved phosphorus). At station HRM 136, the first station downstream from major industrial and municipal discharges, the average concentration of total phosphorus had increased to 0.14 mg/L. These samples were not analyzed for dissolved phosphorus. At the next downstream station (HRM 126) just downstream from Holliston Mills discharge, the average concentration of total phosphorus was 0.20 mg/L. This average concentration of 0.20 mg/L was inflated by a massive increase for three sampling periods during the sampling excursion. The average concentration for those three sampling periods was 0.49 mg/L. The average dissolved phosphorus concentration for this station was .08 mg/L. This fraction of the phosphorus complex was not influenced by a massive increase during the sampling period.

The total phosphorus concentration at Station 120 was still being impacted by the increase recorded at station 126.

Average total phosphorus was 0.20 mg/L but again there was no massive increase in dissolved phosphorus during the sampling period. The average dissolved phosphorus concentration was 0.10 mg/L. The increase in concentration in total phosphorus which occurred at station HRM 126 was somewhat ameliorated at this downstream station; the average concentration during the three sampling periods at this station was 0.44 mg/L.

5.7 Community Metabolism

The diel records for dissolved oxygen (DO), temperature, and oxygen saturation are reported in Table 5.7-1 for stations located at HRM 136.1 and HRM 134.2. The graphical analyses of these data and the appropriate oxygen diffusion coefficients are shown in Appendix A, Figures A-5.1 and A-5.2, Table A-5.1. The estimated gross primary production (GPP) ranged from 11.00 to 14.80 g/m^2/day (Table 5.7-2). Community respiration (R) was somewhat greater than GPP, ranging from 18.00 to 18.20 g/m^2/day (Table 5.7-2).

The reported respiration and production values clearly indicate that plant photosynthesis was not yielding sufficient

DO to meet all the oxygen demanding processes of the river (Table 5.7-2). Without reaeration from the atmosphere, unacceptable levels of DO would be certain to occur at night. The diffusion coefficients (K) suggest a moderate to high rate of exchange of oxygen between air and water (Odum, 1956). Although GPP is a measure of oxygen production by plants, the R values represent oxygen use by numerous processes which include plant, bacteria, and chemical oxidation. If the latter two forms of oxygen demand are viewed as non-vascular plant respiration, the reported R can be reduced by an appropriate value based on BOD and nitrification rates. In this case, the combined value for the two processes, BOD and nitrification, is estimated at about 3.1 g O_2/m^2/day. The modeling section of this report (Appendix E) gives a combined BOD and nitrification value of 2.13 mg/L/day for the vicinity of HRM 136 to HRM 134. The average depth for this reach was estimated at 1.45 m; thus the value of 3.1 g O_2/m^2/day was derived. By adjusting R values for the absence of BOD and nitrification, suspected plant respiration nearly equals plant oxygen production at HRM 136.2, but at HRM 134.2, respiration still exceeds photosynthetic oxygen production.

Using the adjusted respiration values, P:R ratios were calculated to be 1.0 and 0.7 for the stations, respectively.

The P:R ratio serves as an index to plant community maturity. For example, the ratio is high during early stages of growth and low in the climax phase of growth. So long as gross production exceeds respiration, standing crop biomass must accumulate in the community. The reported P:R ratios suggest that the macrophytes in the study reach have attained maturity and to some degree have initiated their seasonal die-back.

The second primary production study involved monitoring the DO and temperature of a defined water mass as it traveled through two reaches of the river--HRM 141.3 to HRM 126.6 and HRM 131.7 to HRM 118.4. The diel DO and temperature observations are reported in Table 5.7-3. Using the same graphical analysis employed in the previous study, GPP and R values were determined for the two reaches (Table 5.7-4).

The production and respiration data (Table 5.7-4) represent average values for the reaches. A major difference exists between GPP and R values given for the two reaches. Regarding the GPP values, the downstream reach yielded an average value nearly 70 % less than for the preceeding upstream stretch. Because the study spanned two photoperiods, differences in available sunlight would appear to be the principal factor effecting the disparity. In Appendix A, Figures A-6.3 and A-6.4, a pyrhelimeter graph is given for the two photoperiods of interest. On the 24th of July, a pronounced decrease in sunlight occurred during mid-day when a rain storm passed through the region. The marked reduction in sunlight correlates with a sharp decrease in GPP (Appendix A, Figures A-6.3 and A-6.4). Assuming that equal light was available for both photoperiods, the normalized value for the July 24 photoperiod would be about 3.3 g O_2/m^2/day which is still substantially less than reported for the previous day. With normalization for light differences, the lower reach (HRM 131.7 to HRM 118.4) appears less productive than the river area between HRM 141.3 and HRM 126.6.

To approximate P:R ratios for the two study reaches, both respiration values were adjusted for the effects of BOD and nitrification. As indicated previously, adjustment factors were derived from the modeling section of this report. In this case, values of 2.90 and 1.70 were obtained for the upstream and downstream reaches, respectively. By subtracting the factors from respective R values, plant respiration was estimated at 6.7 and 3.0 g O_2/m^2/day. Using these figures and normalized production values, P:R ratios of 1.0 and 1.1 were determined for the reaches of HRM 141.3 to HRM 126.6 and HRM 131.7 to HRM 118.4, respectively. As indicated earlier, P:R ratios of about 1.0 represent the metabolism of a plant community at its climax state of seasonal growth.

5.8 Benthic Metabolism

Rates were determined for benthic habitats consisting of periphytic growth on rocky substrate, rooted aquatics with periphytic growth, and a combination of both the above. Monitoring runs were of varying duration with elapsed times as follows:

Run 1	218 min.
Run 2	90 min.
Run 3	262 min.
Run 4	95 min.

Since the runs were not performed simultaneously nor for the same duration, solar radiation influencing photosynthesis in the clear chambers was variable from run to run

(Table 5.8-1). Therefore, for comparison purposes, net production rates were determined on an hourly basis then extended to 13.5 daylight hours which was the normal photoperiod during the study. Respiration, likewise, was determined per hour and then calculated for a 24-hour period. For calculating GPP rates, the average of all respiration rates obtained from the combination of rooted aquatics and rocks with periphyton was utilized so as to integrate rates obtained from substrates with different percentages periphyton and rooted plant colonies. Respiration rates ranged from 4.1 g O_2/m^2/day on Run 1 to a high of 10.7 on Run 4 (Table 5.8-2). Gross primary production rates ranged from a low of 2.5 g O_2/m^2/day on Run 1 to a maximum of 8.00 g O_2/m^2/day on Run 3 (Table 5.8-3). Average respiration and production rates for those runs containing both rooted aquatics and rock periphyton (Runs 2, 3, and 4) were 8.4 and 5.6 g O_2/m^2/day, respectively, which results in a P:R ratio of 0.85.

Biomass (AFDW) samples were collected from within the circumference of each dome position with subsequent determination of plant composition and weight (Table 5.8-4). As previously stated, three habitat types were studied for rate determination. Run 1 was made over a substrate composed of rocks with periphytic growth but void of any rooted aquatics. Runs 2 and 4 were conducted over areas densely vegetated with rooted aquatics, consisting predominantly of sandy substrate which was heavily shaded by the vegetation. Run 3 habitat was a combination of rooted aquatics and rocks with periphyton.

Total daily solar radiation for the dates July 27, 28 and 29 was 609, 567, and 138 langleys respectively (Table 5.8-1). These values were obtained from daytime lengths of approximately 13.5 hours. Since each benthic run was of a considerably shorter period than the day length, solar radiation influencing photosynthesis in the clear domes was substantially less than the above values. Additionally, light extinction experiments revealed that only 12% of the light available at the surface reached the 4-foot depth (Table 5.8-1) where the rates were determined.

It was expected from previous EPA benthic respiration work in Fahkahatchee Bay, Florida (EPA, 1973c) that the benthic rates would show a linear response when normalized for biomass and available light. This was not the case, however, for the Holston River study. Such normalization yielded both

R and GPP rates far in excess than expected, thus leading to two conclusions. Either the plants in the Holston River do not respond to available light in a linear fashion or an insufficient amount of data was collected during the short study period to establish such linearity.

Although normalization was not possible, nevertheless when the obtained hourly respiration rates were extended to a 24-hour day they compared quite favorably with early benthic data obtained on the Holston River by EPA's Cincinnati office in 1969. Data obtained during July 1969 indicated an R rate at HRM 118.8 (4 foot depth) of 5.36 g O_2/m^2/day @ 20°C and of 6.51 g O_2/m^2/day @ 20°C at HRM 124.2 (3 foot depth). Respiration rates of the four runs conducted at HRM 121.6 ranged from 3.15 g O_2/m^2/day @20°C to 9.07 g O_2/m^2/day @20°C (Table 5.8-5).

Respiration values obtained during the four benthic runs that were sampled in July 1977 are quite variable due to variations in the habitat types and their plant compositions. Yet, when averaged, which combines all the biotic and abiotic factors influencing benthic metabolism indigenous to this particular section of the Holston River, the R value is 5.99 g O_2/m^2/day @20°C (Table 5.8-5).

Net primary production was not determined during the July 1969 study. Consequently, no data is available for comparison with net production data developed in the present study. Gross primary production and respiration data obtained by the benthic metabolism method was compared, however, with data obtained using the diel curve method. Although benthic metabolic measurements inherently omit certain metabolic activities measured by the diel method, the P:R ratio developed by the benthic method compares quite favorably with those obtained through diel measurements. When the average respiration value for benthic runs involving both periphytes and macrophytes is adjusted for BOD and nitrification and compared to the gross primary production average for the same runs, a P:R ratio of 0.85 results. Recognizing that a portion of the total community is absent from this value as previously mentioned, it compares well with P:R values of 1.0 and 1.1 obtained through diel monitoring of river segments HRM 141.3 to HRM 126.6 and HRM 131.7 and HRM 118.4, respectively.

5.9 QUAL II Model Simulation

The following comments in this section summarize modeling efforts by Southeast Environmental Research Laboratory personnel. For those interested in further details, a complete report of the modeling can be found in Appendix E.

The QUAL II water quality model (Roesner et al., 1973) was applied to the Holston River from HRM 118 to the confluence of the North and South Fork, the South Fork Holston River to Fort Patrick Henry Dam, and a short reach of the North Fork Holston River. The effects of biochemical oxygen demand and nitrogen compounds from waste discharges and respiration of aquatic plants on the oxygen balance of the stream were simulated. The purpose of the modeling study was to assess the relative impact of current waste discharges and aquatic plant populations on water quality, specifically DO, in the Holston River. Earlier modeling studies by TVA and EPA and by a consultant to the Tennessee Eastman Company had led to the present permit limitations and, thus, to the current wastewater NPDES permit limits. This modeling study relied on information from these earlier investigations and data from the EPA field investigation during July 1977.

The results of the modeling study (Appendix E) indicate that DO levels slightly below 5 mg/L can be expected under conditions of maximum stress on DO, e.g. under conditions of low photosynthetic oxygen production and current waste discharges. Approximately half of the DO deficit under these conditions can be attributed to aquatic plants with the remainder of the deficit largely due to discharges of carbonaceous biochemical oxygen demand. Ammonia-nitrogen discharges have only a small effect on the oxygen balance.

5.10 Cherokee Reservoir

During studies on Cherokee Reservoir the week of July 21, reservoir volume was 931.95 x 10^6 m^3 with a mean elevation of 317.96 m, a maximum depth of 40.54 m and a retention time of 100 days (TVA, personnel communication).

A large volume of Cherokee Reservoir had a very low average dissolved oxygen (DO) level (Table 5.10-1) during the week of July 21st. A definite DO stratification was encountered at all sampling stations. Surface DO levels ranged from 6.0 to 7.5 mg/L at all stations, except Station 86 where levels of 4 to 5 mg/L were encountered (Figure 5.10-1 and Table 5.10-1). Average DO levels less than 1 mg/L were found at depths ranging from 12 to 14 meters and continued unchanged to the bottom of the reservoir (Figure 5.10-1 and Table 5.10-1). The only station where dissolved oxygen did not reach zero was Station 86 where a level of 0.5 mg/L was measured. The National Eutrophication Lake Survey found oxygen levels of less than 1 mg/L at depths greater than 13.7 meters during the summer of 1973 (EPA, 1976a).

Surface to bottom temperatures differed by only one degree centigrade at upstream Station 92 and 7.5 degrees centigrade at downstream Station 55 (Table 5.10-2) near the dam. In the entire reservoir, there was no station at which differences in temperatures between meter depths differed by more than one degree centigrade (Table 5.10-2). There was no discernible thermocline such as one would expect in a large storage reservoir during this period of time. Surface temperatures ranged from highs of 28° - 29°C at downstream Stations 55, 59-60, and 67 to lows of 26°-27°C at upstream Stations 92 and 86 (Table 5.10-2 and Figure 5.10-2). Bottom temperatures varied with the depth of the station sampled and ranged from 25°C at 6 meters depth at upstream Station 92 to 21.5°C at downstream Station 55 at a depth of 26 meters (Table 5.10-2, Figure 5.10-2).

Secchi disk measurements of transparency varied somewhat from the 1973 National Eutrophication Lake Survey (1976a).

Upstream Station 92 had a reading 0.6 meters in 1977 (Table 5.10-3), compared to 1.2 meters in 1973. Readings at Station 75, located near the Morristown sewage treatment plant outfall, were 1.3 meters in 1973 and 2 meters in 1977. The 1977 secchi disk measurements for the near-dam stations were within three-tenths of a meter of 1973 measurements.

Light transmission at the 1% level was determined in an effort to identify the euphotic zone. A gradual increase in the euphotic zone (1% light transmission level) was noted from the upstream stations to those near the dam (1.8 meters to 6.8 meters) (Figure 5.10-3, Table 5.10-3).

Mean levels of total inorganic nitrogen in the euphotic zone of Cherokee Reservoir ranged from 0.90 mg/L at upper Station 92 to 0.07 mg/L at Station 55 located just upstream of the reservoir dam (Table 5.10-4). Inorganic nitrogen levels generally decreased in a downstream direction. Total nitrogen levels at stations in Cherokee Reservoir generally followed the inorganic nitrogen levels, except for Station 55 which had a higher level of total nitrogen than Station 59-60 located just upstream.

Inorganic nitrogen levels in the lower depths of Cherokee Reservoir decreased in amounts from 0.95 mg/L at Station 92 to 0.05 mg/L at Station 55 (Table 5.10-5). Total nitrogen also followed the same pattern with a high of 1.16 mg/L at Station 92 and a low of 0.27 mg/L at Station 55 (Table 5.10-5). A slight increase was seen at Station 75 near the Morristown sewage treatment plant outfall.

Total phosphorus levels decreased from upper to lower reservoir stations and were greater in the lower depths than in the euphotic zone (Tables 5.10-4 and 5.10-5). Euphotic zone levels ranged from a mean of 0.12 mg/L at Station 92 to less than 0.01 mg/L at Station 55 (Table 5.10-4).

An attempt to correlate in vivo chlorophyll samples with their attendant differences resulting from sampling over wide areas and depths soon made it apparent that an insufficient number of discrete chlorophyll a samples had been collected. This made it impossible to use the in vivo samples for analyses so only the discrete chlorophyll a samples are presented in Table 5.10-6.

Chlorophyll a levels (Table 5.10-6) within the euphotic zone of reservoir stations varied with depth. The lowest chlorophyll a levels were at Stations 59-60, and 92, 1.76 and 1.82 mg/m^3, respectively. The greatest chlorophyll a level was 17.16 mg/m^3 at Station 75 near the Morristown sewage treatment plant. The mean level of chlorophyll a in Cherokee Reservoir, 6.01 mg/m^3, is one-half of the mean of 12.2 mg/m^3 measured in 1973 (EPA, 1976a). The levels of chlorophyll a in the euphotic zone of Cherokee Reservoir stations would all be considered mesotrophic, except for Station 92 which would be oligotrophic (EPA, 1975).

The initial algal assay on Cherokee Reservoir waters was conducted with separate additions of nitrogen ranging from 0.3 to 1.2 mg/L and phosphorus ranging from 0.03 to 0.12 mg/L (Table 5.10-7).

Dry weight yield of *Selanastrum* was considerably below that predicted for the untreated Reservoir water control and the nutrient spiked samples (Table 5.10-8). Dry weight yield ranged from 0.9 to 2.4 mg/L regardless of nutrient treatment, suggesting either another limiting nutrient or a toxic substance, that suppressed growth.

In an effort to determine why algal growth was lower than predicted, a second algal assay was conducted with the same Cherokee Reservoir water except it was treated with only one level each of nitrogen (1.0 mg/L) and phosphorus (.05 mg/L) (Table 5.10-9). Nitrogen and phosphorus at these levels were combined together or with 1.0 mg/L of EDTA, an organic chelator. EDTA combines with heavy metals and detoxifies the sample. Nitrogen and phosphorus were also combined in one treatment without EDTA to determine if the yield deficiency was resulting from low levels of both of these nutrients (Table 5.10-9). Another sample of reservoir water was spiked with algal assay media to determine if any of the nutrients found in it may increase growth. A final sample was treated with a spike of a micronutrient mixture to explore the possibility of a low level of some essential micro-nutrient (Table 5.10-9).

The second algal assay dry weight yield (Table 5.10-10) was like the first assay, much lower than that predicted for the control sample and the treated samples. The greatest yield (11.0 mg/L) was from the sample spiked with phosphorus, nitrogen and EDTA (Table 5.10-10). This yield was four times larger than the next greatest yield resulting from the combined phosphorus and EDTA spike. These results indicated that sample waters contained some toxicant which restricted growth, and were also phosphorus limited.

Twenty five metals and their concentration were determined by plasma emission spectroscopic analysis of a Cherokee reservoir raw water sample (Table 5.10-11). Of the metals measured, only three exceeded the mean observed values for the Tennessee River Basin (Kopp and Kroner, 1967). Of these three, manganese and strontium were within the maximum observed Tennessee River values of 11 ug/L and 118 ug/L, respectively. Only aluminum exceeded the maximum observed level of 92 ug/L with a concentration of 150 ug/L. TVA water quality STORET records of Holston River at Surgoinsville, Tennessee (HRM 118.4) show aluminum levels of 300 and 400 ug/L in 1973 and 3000 ug/L in 1974. Little information is available concerning the toxicity of aluminum to aquatic plants. Levels of aluminum exceeding 1000 ug/L were found to depress the growth of some plants (McKee and Wolf, 1963).

6. DISCUSSION

In 1965 (Anon., 1966) the Limnology Department of the Academy of Sciences of Philadelphia conducted a series of biological studies on the Holston River in generally the same area covered by the 1977 EPA study. The Academy found that the area of the river in the immediate vicinity of Kingsport, Tennessee was badly polluted. *Sphaerotilus*, a sewage bacteria, was abundant, the diatom flora was dominated numerically by a single species, *Nitzschia palea*. Invertebrates were almost completely absent and what few fish were present probably came from the North Fork Holston River. At the Smiths Bend station (approximately 8 miles downstream of Kingsport), the aquatic community was beginning to show signs of recovery. The Academy stated that while the community showed certain imbalances resulting mainly from organic enrichment, it was greatly improved from upstream and represented a zone of recovery.

The conditions that existed throughout the 1977 EPA study were quite different from those described by the Academy in

1965. In 1977, the benthic fauna at SFHRM 1.2, located in the immediate vicinity of Kingsport, consisted of a diverse assemblage of organisms. The invertebrates consisted of 45 species representing all of the major groups. Mean diversity at this station was 3.64 (Table 5.3-7). Equitability, a measure of community structure sensitive to organic pollution, was 0.7 indicating that the benthic community was not being severely impacted by organic loading. Fish were present in large numbers feeding in the extensive aquatic weed beds present at this station.

Two stations were located on the main stem of the Holston River downstream from Kingsport. One of these stations was located in the same general location as the Smiths Bend station in the Academy report. As stated earlier, the Academy reported that the aquatic community at Smiths Bend indicated that the area was a "zone of recovery" and while the community still showed stress from organic pollution there was a great improvement from the upstream station. In the 1977 study a diverse assemblage of invertebrates was collected (37 species) at Smiths Bend. The mean diversity value of the quantitative data was 3.38 and equitability was 0.7 (Table 5.3-7). Neither of these values were significantly different at the α.05

probability level from upstream or downstream stations. A limited amount of pole and line fishing within the station area produced yellow bullheads, channel catfish, very large bluegill and redbreast sunfish and smallmouth bass. Several species of minnows were observed but not identified.

Again there was an improvement in the structure of the aquatic community structure when compared to that reported by the Academy in their 1965 study.

The Phipps Bend station, 10 miles downstream from Smiths Bend, also produced 37 species of benthic invertebrates with a mean diversity value of 2.09 and equitability value of 0.2 (Table 5.3-7). The reduction of both mean diversity and equitability was caused by large numbers of one species of mayfly (Stenomema interpunctatum) and a snail (Goniabasis sp.). Both of these invertebrates were intimately associated with the extensive plant beds in the river at this station. This, rather than a change in water quality, accounts for their numerical abundance. Even though there was a reduction in diversity the difference was not significant at the $\alpha.05$ probability level from either the upstream station or the station on either the South Fork Holston River or the North Fork Holston River. This does not imply that the species composition is the same at all stations. On the contrary, the benthic community of the North Fork Holston contains several clean water species (_Neureclipsis_ _crespuscularis_, _Helicopsyche_ sp., _Psephenus_ sp., _Stenonema_ _exiguum_, and _Cladotanytarsus_ sp.) that were not found in either the South Fork or the main stem of the Holston.

When comparing the EPA 1977 benthic community data plus observations on the fish fauna with the 1965 Academy study, it is obvious that there has been a considerable improvement in the water quality of the Holston River. After careful scrutiny of the 1977 data, though, it is also apparent that the stream is still being impacted by perhaps both the impoundment and the dischargers upstream.

In addition to the invertebrate studies, periphyton information was accumulated to reinforce the invertebrate results and aid in determining whether inorganic enrichment was a prevalent problem. Vollenwieder (1968) in his studies considered waters to be enriched if periphyton chlorophyll _a_ concentrations ranged from 0.020 to 0.140 g/m^2. Chlorophyll _a_ values ranging from 0.054 to 0.142 g/m^2 in the 1977 Holston study are within Vollenweider's range for enriched waters.

For several years TVA has conducted biological studies in the Phipps Bend area (TVA, 1976) and near John Sevier Steam Plant (TVA, 1977) further downstream. Chlorophyll *a* values for a three year period (1973 through 1975) in the summer ranged from 0.00005 g/m^2 on September 5, 1973 at HRM 106.5 to 6.85 g/m^2 on August 6, 1975 at HRM 106.2. Greatest concentration near the steam plant was recorded on November 11, 1974 when a chlorophyll *a* concentration of 23.01 g/m^2 was attained at HRM 106.5. Further upstream at Phipps Bend in 1974-1975 TVA found periphyton chlorophyll *a* values ranging from 0.00492 g/m^2 to 0.1478 g/m^2. Values determined in 1977 by EPA of 0.020 g/m^2 to 0.140 g/m^2 of chlorophyll *a* are substantially less than TVA's maximum values at John Sevier Steam Plant, but somewhat similar to TVA's values at Phipps Bend. Values of chlorophyll *a* found at Phipps Bend are typical of those in tailwater releases at other dams located in the Tennessee Valley (TVA, 1976).

By evaluating the ratio of biomass to chlorophyll *a* in the form of the autotrophic index (AI), insight can be gained into community function. Low AI's of approximately 100 indicate that algae predominate in the periphyton community presumably as a result of inorganic nutrient enrichment (Weber and McFarland, 1969). As the periphyton community tends toward more heterotrophy with a predominance of fungi, bacteria and protozoa, the AI's will increase and at values greater than 1000 one can surmise that the community is influenced principally by organic inputs upstream. Serious organic pollution problems were not detected in the AI values determined for 1977. In fact, AI values ranging from 37.4 to 140.6 indicate inorganic rather than organic nutrient enrichment is one of the major controlling influences on the periphyton community. Low AI values have not been uncommon in the past few years as TVA (1976) in 1974-1975 only recorded a maximum AI of 14.57 which is much less than that found in 1977.

The periphyton data reinforces the invertebrate findings that conditions are improving with respect to organic pollution loading; however, the periphyton data indicate that inorganic nutrient enrichment from dam tail waters and other point and non-point sources are impacting the Holston system. Although nutrient enrichment is impacting the Holston, there are indications that its effects are declining because the alga Cladophora, a predominant feature in 1969 (EPA, 1972), did not exhibit luxuriant growth in 1977.

Visual impressions of luxuriance are primarily determined by apparent areal cover of the vegetation. Presently there are few works relating riverene aquatic plant cover to loads of pollutants; however, a few available works give us some insight into what can be expected.

Kullberg (1974) in his distribution studies of aquatic plants in a southern Michigan stream estimated that cover by macrophytes in the upstream unpolluted (unpopulated and uncultivated with no point discharges) portion was 41.4%. Of this plant cover, *P. pectinatus* was predominant and represented 44% of all plant cover. No attempts to estimate plant cover downstream of a paper mill discharge was attempted because of deep sludge beds which prohibited working in the stream.

Southwick and Pine (1975) studying the abundance of submerged vascular vegetation in the Rhode River considered plants abundant if 70% or more of the water surface was covered with aquatic plants; common if coverage ranged from 20 to 70% of the surface or bottom; occasional if there was 5 to 20%

coverage and sparse for less than 5% coverage. Percent weed cover for the segments of the Holston under consideration would be considered common under Southwick and Pine's (1975) classification but not abundant.

In work conducted at Phipps Bend by TVA (1976) aquatic plant cover including mosses ranged from 9 to 92% when the river was segmented in 0.5 river mile sections. Coverage greater than 70% can be cause for concern because of possible negative effects on the oxygen budget. For the entire stretch of river from HRM 118.0 to HRM 126.5 (8.5 river miles) percent areal cover amounted to 50.6% (TVA, 1976). This percent cover is 16.8% less than that found for the Holston River (Segment 1) in 1977.

Where submerged and floating leaved plants are concerned, areal cover can be misleading, especially with regard to production of standing crop because of the typically high aquatic plant volume to dry weight ratio of many species, the lack of substantial underground organs, the preference of certain aquatic plants (e.g. Potamogeton) for shallow waters where the ratio of occupied volume of water to occupied surface area is small, and their habitat of floating in masses with their long flexuous shoots trailing downstream in flowing water. So although the percentage areal cover of submerged communities may be high, their weight per unit area is often small (Sculthorpe, 1967).

This is partially the case in the Holston River. Percent cover in some stretches of the Holston were relatively high but standing crop dry weight (DW) and ash-free-dry weight (AFDW) were low to moderate.

Estimates of standing crop weights for riverine systems are few, but available reports give us some indication of what can be expected in rivers. Odum (1957) in his work at Silver Springs, Florida found up to 621 g/m^2 chlorophyllous DW during his productivity studies. Edwards and Owen (1960) estimated on the unpolluted reach of the River Ivel, a fertile chalk stream, up to 519 g/m^2 chlorophyllous DW and in a reach polluted by sewage they found only up to 235 g/m^2. In another study on the River Test, Owens and Edwards (1961) recorded in this clean fertile lowland river up to 385 g/m^2 chlorophyllous DW. Further studies on the River Yare (Edwards and Owens, 1962), a mildly polluted river, produced chlorophyllous DW yields of 381 g/m^2. Hannan and Dorris (1970) in studies on the Marco River found a maximum chlorophyllous DW of 43 g/m^2 in gravel beds and 355 g/m^2 DW in mud beds. Average chlorophyllous DW for the stretch studied was 231.5 g/m^2.

In plant beds on the Holston River (segment 1) where moss did not predominate, the maximum average chlorophyllous standing crop DW was 371.38 g/m^2 in 1977. This value was less than that found by the above investigators, Odum, Owens and Edwards. The maximum average chlorophyllous DW at Surgoinsville was slightly greater than the maximum found in the Marco River (Hannon and Dorris, 1970).

The other known estimates of standing crop weight for the Holston River besides the 1969 EPA study, are those of Peltier and Welch (1969) and TVA (1976).

Peltier and Welch (1969) in their studies on factors affecting growth of rooted aquatics in the Holston collected aquatic plant biomass (AFDW) data at 3 sites in 1967; HRM 132.8 near the Holston Army Ammunition Plant, HRM 118.0 at Surgoinsville, and HRM 112.0 near Bussels Bend. Highest average total biomass (AFDW) found in the 1977 study (10 years later) of 238.34 g/m^2 was less than the minimum average total AFDW of 248.8 g/m^2 found by Peltier and Welch near Bussels Bend.

TVA (1976) in their studies of the Phipps Bend site in 1974 and 1975 determined that the maximum chlorophyllous standing crop biomass (AFDW) was 250 g/m^2 in beds where Sago Pondweed predominated. At the 1977 Phipps Bend sites the maximum average chlorophyllous biomass of 198.02 g/m^2 was somewhat less than that found by TVA.

According to Westlake (1963), aquatic plants growing on fertile sites can range from 200 g/m^2 to 10,000 g/m^2 DW. Several sites sampled in the 1977 study were within this range except NFHRM 4.5 (127.80 g/m^2 total DW) and the Smith's Bend site (66.66 g/m^2 total DW).

Flowering in _H. dubia_ an _V. americana_ in late July when samples were collected plus the fact that reported P:R ratios were near 1.0 indicate that the 1977 sampling occurred at or very near peak net production of biomass. Data presented in Sculthorpe (1967) indicate that from 1-6 metric tons AFDW/ha net production can be found in temperate flowing waters. Greater production from 10-21 metric tons AFDW/ha can be found in subtropical habitats, and tropical marine angiosperms may attain up to 30 metric tons AFDW/ha. Average AFDW ranged from 0.13 metric tons/ha of river in the North Fork (Segment 3) to 0.64 metric tons/ha of river in the South Fork (Segment 2) in 1977. These 1977 values are below what would be expected in temperate flowing waters.

Leaf area index (LAI) is a structural measurement defined as surface area of live leaves (one side only) per unit area. The maximum biomass in any aquatic plant community is related to density as a function of leaf size. This is essentially a control by light through shading; that is, there must be some density of leaves that results in increasing self shading and becomes a controlling factor. The LAI is an estimate of this maximum leaf density. In terrestrial cereal crops, maximum values of the LAI are as high as 9; for broad-leaved trees in a tropical rain forest it can reach 20 and in seagrass meadows LAI's greater than 20 can be attained. The consequence of increasing the bottom area by more than 20 times is, of course, extremely important to other inhabitants of the community (McRoy and McMillan, 1977).

Unmanaged aquatic macrophyte LAI data are scarce but Nicholson and Best (1974) and Ikusima (1970) provide us with some insight into the range of values found in fresh-water aquatic plant communities.

Ikusima (1970) in studies on light condition and community photosynthetic production found for floating plants that it ranged from 1.0 in Trapa incisa to 2.1 in Nymphoides peltata populations. Total biomass standing crop in these populations ranged from 118 to 348 grams DW/m^2.

Nicholson and Best (1974) in studies on leaf area relationships generalized that for freshwater undisturbed submergent aquatic communities one could expect LAI's up to 7 whereas LAI's of 10 or greater may indicate increased nutrient enrichment. LAI's calculated for selected plant beds in the Holston River system were relatively low, ranging from 0.01 to 1.0 m^2/m^2. These 1977 LAI's for the Holston are more closely assocated with LAI's of floating plant communities rather than submerged communities, and they are well below LAI's associated with nutrient enrichment in fresh or saline waters where 10-20 or greater can be expected.

Gerloff (1969) in studies involved with evaluating nutrient supplies for the growth of aquatic plants in natural waters' determined for H. dubia and V. americana, two of the predominant Holston River species, that the critical nitrogen and phosphorus percent concentration of the DW was 1.3%

nitrogen for both species and 0.13% phosphorus. Anything greater than these percentages is luxury consumption, that is, amounts greater than the minimum content of an element necessary for maximum growth. The transition point, at which storage without additional growth starts to occur, defines a critical concentration so that if plants are found in nature containing less of the element, it is reasonable to presume that they are limited by an element in question. Tissue contents above the critical level have no effect on yields. *H. dubia* and *V. americana* collected in the Holston had greater percent nitrogen of respectively 1.78% and 2.04% of the DW than the 1.3% critical level established by Gerloff. Total percent phosphorus of DW in *V. americana* was 0.30% and in *H. dubia* 0.25%. Again these two plants species contained concentrations beyond the critical limits in their tissues indicating ample accumulation of both nutrients. Peltier and Welch in their 1967 Holston studies calculated for plants at three stations that percent nitrogen of DW ranged from 2.0% to 3.1% and phosphorus ranged from 0.31% to 0.43% of the DW. For plants in the 1977 study, a maximum of 2.27% nitrogen was found in *P. pectinatus* and 0.30% phosphorus in *V. americana*. Maximum percent nitrogen and phosphorus found in the 1977 study was 0.83% and 0.13% respectively less than maximums found by Peltier and Welch (1969). Although 1977 percent nutrient data is still beyond critical limits, it is still noteworthy to see a reduction in nutrient tissue content.

In a habitat such as exists in the study area, it would be reasonable to expect that the copious amounts of aquatic plants present within the area would utilize a fair proportion of the nutrients being deposited in the river, especially since the river bottom is mostly rock without large sediment deposits present. If the plants were utilizing the nutrients deposited in the river, then a reduction in the concentration of nutrients should occur in the downstream stations provided there are no further inputs into the system downstream.

Since the nitrogen data presented in the Budget Sections does not show a reduction downstream but instead a steady increase at the successive downstream stations, it is obvious that either (1) there are more inputs into the system in the downstream area, or (2) that the plants are not taking up nitrogen as indicated by the luxuriant percentage amounts of nutrients in them, but are instead adding to the original loading. As mentioned earlier, groundwater into the system was not measured and is probably responsible for a portion of the surplus nitrogen recorded at the downstream stations. It is impossible to tell how much nitrogen is getting into the river from this source, but the amount is probably considerable because there is an appreciable amount of farming done in the floodplain of the river within the study area. Input from groundwater varies with the season and as expected has its greatest significance during the rainy season when the groundwater supply is fully replenished. Under first consideration it would seem that the greatest input would occur just after the farmers have fertilized their crops in the spring and the fertilizer is leached from the soil. Stanly and Hobbie (1977), however, in their work on the Chowan Estuary found that the heaviest input was in the winter after the fall and winter rains when the depleted groundwater supply was replenished.

The effects of surface runoff was probably negligible for the first half of the study but then locally heavy rains fell throughout the watershed of the study area which undoubtedly influence the measured concentrations of nutrients during that period of the study.

In addition to the two sources mentioned above, it is also possible that plants are releasing stored nitrogen as a regular function of their metabolism or even through fragmentation by the turbulence of the fluctuating water levels.

A comparison of the nitrogen data between steady state and fluctuating condition is interesting. In all cases, the lbs/hr loading for the fluctuating flow is significantly higher than that for the steady state condition. Unfortunately, the data from the fluctuating flow conditon is probably influenced to a greater degree than the steady state condition by the rain that fell during the study. In addition, the calculated concentration for the fluctuating flow condition may be high because a full cycle of the massive fluctuation in water level did not pass during the collection period. So possibly the absolute difference in load level is not as important as the fact that there is a difference between the two situations and that using steady state conditions to estimate what happens in a river that has "natural" daily fluctuations may have some important inherent problems.

Phosphorus enters surface streams mainly through surface runoff and waste discharges. Undoubtedly, further amounts enter streams through groundwater infiltration and precipitation. The assimilation rates of this phosporus in a stream are rapid (Keup, 1968) and stream biota are the primary mechanisms of uptake. Ultimate disposal from the waterway, however, is not by the biota but by loss to the sediment or downstream dispersal by bed load movement or surface floating materials. The phosphorus which is temporarily lost or stored in the sediment is subsequently scoured or resuspended during rising water levels but is ultimately redeposited when the velocities are reduced.

During the 1977 study, both sources of surface water (North and South Fork of the Holston River) contained 40 ug/L of total phosphorus and 20 ug/L of dissolved phosphorus. Upstream from Station HRM 136 the two water sources merge and industry and domestic waters discharge into the river. The concentration of total phosphorus at Station HRM 136 is 140 ug/L. EPA (1976) recommends that total phosphates as phosphorus should not exceed 50 ug/L in any stream where it enters a reservoir. EPA further states that a desired goal for the prevention of plant nuisances in streams not discharging directly to lakes or impoundments is 100 ug/L. The river at Station HRM 136 is exceeding both of those recommendations.

At the next two downstream stations [HRM 126 and HRM 120 (120 is near the headwaters of John Sevier detention reservoir)] the concentration of total phosphorus is 200 ug/L. As stated earlier this increase from the upstream station is the result of an approximately six-hour "slug" of total phosphorus which passed by both stations. An examination of the data shows that there was no great increase in dissolved phosphorus so the increase must be attributed to particulate phosphorus. At approximately the time of the "slug,"the flow in the river changed from a low flow steady state to a high flow fluctuating condition. This probably caused resuspension of phosphorus in the sediment which could account for the massive increase in particulate phosphorus. There is considerable doubt that this is the explanation for the "slug" for two reasons. First, this increase is not documented at Station HRM 136 which is upstream and should show a similar "slug," and second, the duration of the "slug" is too long and the end too abrupt. Another explanation for the increase is the possibility of a release from industry upstream. Two major industries, both of which discharge phosphorus, are located approximately two miles ustream from Station HRM 126 and downstream from Station HRM 136. The problem with this explanation is that these industries discharge only small amounts of phosphorus daily--an amount required to produce the recorded increase in 170.5 m^3/s (6000 cfs) of water is probably too large to be attributed to those industries alone.

Irregardless of the cause of the "slug" going down the river, the concentration within the river is considerably higher than that recommended by EPA (1976) for streams discharging into a lake or reservoir like Cherokee Reservoir. According to Taylor (1971), Cherokee Reservoir is the most eutrophic of the TVA reservoirs. It is characterized by lack of summer thermocline but DO stratification begins as early as March and is concluded by June.

During the 1977 study dissolved oxygen levels at stations downstream from HRM 86 in Cherokee Reservoir were zero at 13 to 14 meters. This zero level was close to the depth reached by water of the temperature coming into Cherokee Reservoir. This water temperature of 26°C was found at depths of 11-16 meters and is probably the lower depth of surface mixing. Solar radiation and the wind induced turbulence in Cherokee Reservoir influences water temperature to a depth of about 12.2 meters according to Wunderlich (1971). This depth included the euphotic zone of Cherokee Reservoir which was limited to a maximum of seven meters.

With Holston River waters overflowing the waters of Cherokee Reservoir, aeration of the surface layers is replenished by reareation of the surface film and photosynthesis (Taylor, 1961). Dissolved oxygen is of a high level during the winter period, but depletes quickly during the spring and summer (Gordon and Nicholas, 1974). Dissolved oxygen depletion in Cherokee Reservoir is the greatest of all TVA reservoirs and the level of DO in the turbine discharge becomes unsatisfactory earlier in the spring and remains longer than any other TVA reservoir (Gordon and Nicholas, 1974). The mean depth at which the DO level in Cherokee Reservoir was 1 mg/L or less for the July - August period of 1968, 1969, 1970, 1973, 1976 and 1977 (Figure 5.10-4) ranged from 11.3 - 15.2 meters near the dam (HRM 55) to 9.2 - 18.0 meters near Morristown (HRM 75), and 10.5 - 16.0 meters at the headwaters (HRM 86). The deepest penetration of the 1.0 mg/L DO level occurred in 1973 and the least penetration occurred in 1969. Nitrification of ammonia consumes a considerable amount of oxygen in Cherokee Reservoir (Gordon and Nicholas, 1974). One mg of ammonia requires 433 mg of oxygen to completely oxidize it (Gordon and Nicholas, 1974). With summer on-set, the oxygen available at greater depths is largely used up by ammonia nitrification. The ammonia concentration increases throughout the summer from such sources as bottom sediments, precipitation of organics, and a breakdown of organic materials carried into the reservoir by the Holston River from upriver sources (Gordon and Nicholas, 1974).

Chemical analyses of water samples collected at various depths of Cherokee Reservoir stations were compared. The highest levels of total nitrogen, inorganic nitrogen, and total phosphorus were found at headwater Station HRM 92 and the lowest at downstream Station HRM 55 near the dam. A similar trend occurred in 1973 (EPA, 1976a). As in 1977, samples collected from greater depths in 1973 had a greater percentage of ammonia than nitrite-nitrate nitrogen, indicating that reactions favoring the production of ammonia are dominant. In bottom sediments and anoxic waters of lakes, nutrient regeneration by bacteria and fungi is the dominant process (Brezonik, 1973).

Phosphorus levels followed the same pattern as the nitrogen in the 1977 survey. Highest levels were at upstream stations and generally at lower depths. A large part of the phosphorus that enters water bodies is precipitated out by adsorption and chemical oxidation (Lee, 1973). In 1973, phosphorus levels of samples also increased with depth of station and in a downstream manner (EPA, 1976a). Phosphorus levels in samples taken at the same depths were of similar levels during the August 1973 and July 1977 sampling periods.

Nitrogen to phosphorus (N:P) ratios are useful in predicting the nutrient that will limit growth of phytoplankton. N:P ratios of 5:1 to 15:1 are commonly reported for algae (Garside, *et al*. 1976). The average N:P ratio has been reported at about 10:1, the point where nitrogen and phosphorus are in balance for the needs of a particular alga. Water containing N:P ratios less than 10 may be considered nitrogen limited, while those with N:P ratios greater than 10 may be considered phosphorus limited (Harvey, H., 1940). Cherokee Reservoir tends to be phosphorus limited. The overall Total N:Total P ratio of Cherokee Reservoir filtered and autoclaved algal assay water was 14.8:1 indicating a tendency toward phosphorus limitation (Table 5.10-12). This ratio is similar to the August, 1973 N:P ratio of 15:1 reported by the National Eutrophication Lake Survey (EPA, 1976a).

To better estimate the maximum potential algal growth response to available nutrients (i.e. nitrogen and phosphorus), algal assays were conducted during the 1973 (EPA, 1976a) National Eutrophication study and in 1977 by Region IV. Both 1973 and 1977 algal assays showed that phosphorus was limiting to growth, but algal maximum yields were much less than predicted in controls and spiked cultures. The limited growth of both the 1973 and 1977 algal assays suggests the presence of some unidentified toxicant.

In 1973, Cherokee Reservoir was included in the lake program of the National Eutrophication Survey. One objective of the survey was to assign a trophic index number to the surveyed lakes. Six parameters were incorporated into this number. They were orthophosphorus, total phosphorus, inorganic nitrogen, chlorophyll a, dissolved oxygen, and Secchi disk reading (Table 5.10-13).

The levels of the above parameters collected from Cherokee Reservoir in 1977 were compared to similar 1973 data from 16 other TVA reservoirs, and a percentage of the reservoirs that exceeded Cherokee in each parameter was computed (Table 5.10-14). The percentages were summed, and this number was assigned to Cherokee Reservoir as the Trophic Index Number (Table 5.10-14). In general, lakes or reservoirs with a trophic index of 500-600 correspond to a very good trophic condition and are oligotrophic, with the transition to mesotrophic beginning in the 500-525 range. Below 420, the lakes become progressively more eutrophic. Cherokee Reservoir was rated at 162 in 1973, and 363 in the 1977 survey (Table 5.10-14). A rating of 363 still denotes a high potential for algal blooms (EPA, 1974b); however, the increase in trophic index number represents an improvement in water quality from 1973.

When put in perspective, Holston River aquatic plants are still the recipients of ample inorganic nutrients but the plants are declining (especially Cladophora) and their cover and biomass are not excessive when compared to other temperate riverine systems and past knowledge of the Holston. This decline in aquatic plant growths coupled with the macroinvertebrate data, water quality data and the modeling effort indicates that the Holston River is improving because of past clean-up efforts in and around Kingsport which have reduced point source loading substantially. When NPDES violations are corrected, additional improvement in oxygen levels are foreseen, especially in the upper reaches of the Holston, where BOD still has the greatest effect on oxygen levels.

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TABLES

TABLE 5.1-1
NET INDUSTRIAL WASTEWATER DISCHARGES TO THE HOLSTON RIVER
KINGSPORT, TN
JULY, 1977

AVERAGE CONCENTRATION MG/L

FACILITY	STATION NO.	MILE POINT	TYPE OF SAMPLE	BOD5	TKN	NH3-N	NO2 NO3	TP
TENNESSEE EASTMAN CORPORATION	TE002	SFHRM 4.5	COMPOSITE	15.1	8.26	4.71		3.89
HOLSTON ARMY AMMUNITION PLANT AREA A	HA001A	SFHRM 4.3	COMPOSITE	4.5	18.25	15.48		0.02
	HA001B	SFHRM 4.3	COMPOSITE	1.6	0.04	0.09	0.02	
	HA014	SFHRM 4.0	COMPOSITE	31.1	9.81	7.50		11.27
MEAD PAPER	ME001	SFHRM 2.4	COMPOSITE	37.9	3.92	0.35		< 0.63
KINGSPORT WTP	KS001E	SFHRM 2.3	COMPOSITE	21.1	9.82	8.35		6.07
HOLSTON ARMY AMMUNITION PLANT AREA B	HB005P	HRM 139.6	COMPOSITE	120.7	1.79	0.16	0.60	0.27
	HB005W	HRM 139.6	COMPOSITE	2.0	0.29	0.28	0.51	0.13
	HB006	HRM 139.1	COMPOSITE	14.4	0.37	0.24	0.59	0.13
	HB008	HRM 139.1	COMPOSITE	2.1	0.27	0.15	3.52	0.09
HOLLISTON MILLS	HM001	HRM 128.4	COMPOSITE	325.6	7.74	1.05		3.40

AVERAGE LOAD LB/DAY

FACILITY	STATION NO.	MILE POINT	TYPE OF SAMPLE	BOD5	TKN	NH3-N	NO2 NO3	TP
TENNESSEE EASTMAN CORPORATION	TE002	SFHRM 4.5	COMPOSITE	2025	1159	636		541
HOLSTON ARMY AMMUNITION PLANT AREA A	HA001A	SFHRM 4.3	COMPOSITE	116	473	400		1
	HA001B	SFHRM 4.3	COMPOSITE	68	4	4	1	
	HA014	SFHRM 4.0	COMPOSITE	86	27	21		31
MEAD PAPER	ME001	SFHRM 2.4	COMPOSITE	3925	378	33		< 61
KINGSPORT WTP	KS001E	SFHRM 2.3	COMPOSITE	1162	556	467		335
HOLSTON ARMY AMMUNITION PLANT AREA B	HB005P	HRM 139.6	COMPOSITE	1313	19	2	7	3
	HB005W	HRM 139.6	COMPOSITE	224	33	31	58	15
	HB006	HRM 139.1	COMPOSITE	1683	43	28	69	15
	HB008	HRM 139.1	COMPOSITE	313	41	23	529	14
HOLLISTON MILLS	HM001	HRM 128.4	COMPOSITE	1145	28	4		13

TABLE 5.1-2
INDUSTRIAL WASTEWATER DISCHARGES TO THE HOLSTON RIVER
KINGSPORT, TN
JULY, 1977

AVERAGE CONCENTRATION MG/L

FACILITY	STATION NO.	MILE POINT	TYPE OF SAMPLE	BOD5	TSS	COD	TKN	NH3-N	NO2 NO3	TP	TOC
TENNESSEE EASTMAN CORPORATION	TE002	SFHRM 4.5	COMPOSITE	16.7	36.0	96	8.41	4.73	0.06	3.870	34.5
HOLSTON ARMY AMMUNITION PLANT AREA A	HA001A	SFHRM 4.3	COMPOSITE	6.1	8.0	<40-66	18.40	15.50	0.58	0.053	7.9
	HA001B	SFHRM 4.3	COMPOSITE	3.2	6.0	< 40	0.19	0.11	0.61	0.033	2.2
	HA014	SFHRM 4.0	COMPOSITE	32.7	105.0	78	9.96	7.52	0.58	11.300	21.2
MEAD PAPER	ME001	SFHRM 2.4	COMPOSITE	39.5	104.0	286	4.07	0.37	<0.01	<0.660	71.3
KINGSPORT WTP	KS001E	SFHRM 2.3	COMPOSITE	22.7	31.0	106	9.97	8.37	0.48	6.100	40.2
HOLSTON ARMY AMMUNITION PLANT AREA B	HB005P	HRM 139.6	COMPOSITE	122.3	104.0	142	2.06	0.22	0.70	0.300	34.3
	HB005W	HRM 139.6	COMPOSITE	< 4	8.0	< 40	0.56	0.34	0.61	0.160	3.2
	HB006	HRM 139.1	COMPOSITE	> 12.0	16.0	< 40	0.64	0.30	0.69	0.160	8.3
	HB008	HRM 139.1	COMPOSITE	3.7	12.0	< 40	0.54	0.21	3.62	0.120	3.0
HOLLISTON MILLS	HM001	HRM 128.4	COMPOSITE	327.0	140.0	608	8.14	1.37	<0.01	3.533	325.0
	HM002	HRM 128.4	GRAB	< 2.0	3.0	< 40	0.33	0.01	0.57	1.000	2.0

AVERAGE LOAD LB/DAY

FACILITY	STATION NO.	MILE POINT	TYPE OF SAMPLE	BOD5	TSS	COD	TKN	NH3-N	NO2 NO3	TP	TOC
TENNESSEE EASTMAN CORPORATION	TE002	SFHRM 4.5	COMPOSITE	2240.0	4980	13500	1180.00	639.00	8.50	545.00	4810.0
HOLSTON ARMY AMMUNITION PLANT AREA A	HA001A	SFHRM 4.3	COMPOSITE	157.0	214	<1035-1700	477.00	401.00	15.00	1.36	204.0
	HA001B	SFHRM 4.3	COMPOSITE	135.0	250	< 1670	7.83	4.70	25.50	1.36	93.9
	HA014	SFHRM 4.0	COMPOSITE	90.0	291	216	27.40	20.70	1.60	31.10	58.5
MEAD PAPER	ME001	SFHRM 2.4	COMPOSITE	4089	9950	27500	392.00	34.90	< 1	< 64.20	6880.0
KINGSPORT WTP	KS001E	SFHRM 2.3	COMPOSITE	1250.0	1760	6010	565.00	468.00	27.30	337.00	2270.0
HOLSTON ARMY AMMUNITION PLANT AREA B	HB005P	HRM 139.6	COMPOSITE	1330.0	1130	1540	22.40	2.44	7.65	3.31	373.0
	HB005W	HRM 139.6	COMPOSITE	< 313.0	895	< 4470	63.20	37.70	68.80	17.90	363.0
	HB006	HRM 139.1	COMPOSITE	>1400	1930	< 4670	74.80	35.10	81.20	18.10	970.0
	HB008	HRM 139.1	COMPOSITE	551.0	1750	< 6010	81.60	32.10	544.00	18.00	451.0
HOLLISTON MILLS	HM001	HRM 128.4	COMPOSITE	1150.0	523	2270	30.40	5.14	< 0.04	13.30	1220.0
	HM002	HRM 128.4	GRAB	< 0.1	0	< 2	0.02	0.00	0.03	0.05	0.1

TABLE 5.1-3

COMPARISON OF 1969 AND 1977 WASTE SOURCE DISCHARGE LOADINGS
HOLSTON RIVER, KINGSPORT, TENNESSEE

	BOD_5				T-N				T-P			
	1969		1977		1969		1977		1969		1977	
Facility	Load[1]	Percent[2]	Load	Percent	Load	Percent	Load	Percent	Load	Percent	Load	Percent
Tennessee Eastman	69,300	50.4	2,240	17.6	16,120	73.6	1,189	32.1	1,784	88.4	545	51.9
Holston Army Ammunition												
Area A	23,480	17.1	382	3.0	10	<.1	554	15.0	29	1.4	34	3.2
Area B	32,220	23.4	3,594	28.3	5,505	25.1	944	25.5	27	1.3	57	5.4
Mead Paper	11,700	8.5	4,089	32.2	60	0.3	393	10.6	4	0.2	64	6.1
Kingsport WTP	500	0.4	1,250	9.8	180	0.8	592	16.0	152	7.5	337	32.1
Holliston Mills[3]	320	.2	1,150	9.1	30	0.1	30	0.8	21	1.0	13	1.2
TOTALS	137,520	100.0	12,705	100.0	21,905	100.1	3,702	100.0	2,017	100.0	1,050	100.0

[1] In Total lbs./day

[2] Percent of combined parameter load

[3] 1969 Data may be off by factor of 10 at Holliston Mills

[4] $\frac{\text{Pounds}}{2.205}$ = kilograms

TABLE 5.3-1
ONE-WAY ANALYSIS OF VARIANCE (.05 LEVEL).
TAXA PER ARTIFICIAL SUBSTRATE SAMPLE.
HOLSTON RIVER. JULY-AUGUST, 1977

Stations tested	Table F values	Calculated F values
NFHR4.2, SFHR1.2, HR134, HR122.8	4.07	0.31
SFHR5.75, SFHR1.2	7.71	0.60
SFHR1.2, HR134, HR122.8	5.79	0.86
HR134, HR122.8	7.71	0.44

TABLE 5.3-2

ONE-WAY ANALYSIS OF VARIANCE (.05 LEVEL).
INDIVIDUALS PER ARTIFICIAL SUBSTRATE SAMPLE
HOLSTON RIVER. JULY-AUGUST, 1977

Stations tested	Table F values	Calculated F values
NFHR4.2, SFHR1.2, HR134, HR122.8	4.07	2.07
SFHR5.75, SFHR1.2	7.71	2.63
SFHR1.2, HR134, HR122.8	5.41	2.03
HR134, HR122.8	7.71	2.51

TABLE 5.3-3

MEAN DIVERSITY ($\bar{d}$) AND EQUITABILITY (e) VALUES FROM ARTIFICIAL SUBSTRATE SAMPLERS. HOLSTON RIVER. JULY, 1977

Station	No. Taxa	No. Individuals	$\bar{d}$	e
North Fork Holston River Mile 4.2	15	110	2.50	0.47
	21	97	2.95	0.48
"	19	128	3.08	0.63
"	11	199	1.47	0.27
South Fork Holston River Mile 5.75	10	115	1.00	0.20
"	19	392	2.42	0.37
"	16	321	2.63	0.50
"	14	170	2.47	0.50
South Fork Holston River Mile 1.2	16	60	3.39	0.94
"	18	120	2.64	0.44
Holston River at Smith Bend	18	68	3.48	0.89
"	14	66	3.05	0.79
Holston River at Phipps Bend	12	448	1.09	0.17
"	16	285	2.05	0.31
"	15	135	2.54	0.53
"	16	124	3.07	0.69

TABLE 5.3-4

ONE-WAY ANALYSIS OF VARIANCE (.05 LEVEL) COMPUTED ON DIVERSITY VALUES AT HOLSTON RIVER STATIONS. JULY-AUGUST, 1977

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio
Mean				
Among groups	3	4.764	1.588	3.1978
Within groups	12	5.959	.4965	

$F_{(.05)(3,12)} = 3.4903$

TABLE 5.3-5

PERIPHYTON. HOLSTON RIVER.
JULY-AUGUST, 1977

Station	Average Chlorophyll a (g/m^2)	Average Biomass (g/m^2)	Average Autotrophic Index (AI)	AI Standard Deviation	Average Chlorophyll a: Pheophytin a Ratio
South Fork Holston River Mile 1.2	0.054	2.88	55.25	7.99	1.42
South Fork Holston River Mile 5.6	0.135	7.15	51.73	11.01	1.53
North Fork Holston River Mile 4.5	0.142	5.28	37.37	4.47	1.35
Holston River Mile 135.4	0.105	5.31	46.65	17.01	1.58
Holston River Mile 122.8	0.066	8.47	140.56	22.30	1.50

TABLE 5.3-6

DUNCAN'S MULTIPLE RANGE TEST FOR AUTOTROPHIC INDEX. HOLSTON RIVER. JULY-AUGUST, 1977

$S_m = 6.125$

Shortest significant ranges

	(2)	(3)	(4)	(5)
R	24.053	24.580	24.702	24.702

Results

Location	NFHRM 4.5	HRM 135.4	SFHRM 5.6	SFHRM 1.2	HRM 122.8
Means	37.37	46.65	51.73	55.25	140.56

←————————————————→ *

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*Any two means not underscored by the same line are significantly different at the .05 probability level.

S_m = Standard error of each mean

R = Shortest significant ranges

TABLE 5-3.7

MEAN MACROINVERTEBRATE DIVERSITY ($\bar{d}$) AND EQUITABILITY (e) VALUES FROM POOLED ARTIFICIAL SUBSTRATE SAMPLES. HOLSTON RIVER. JULY, 1977

Station	$\bar{d}$	"e"
NFHRM 4.2	2.69	0.[illegible]
SFHRM 5.75	2.61	0.3
SFHRM 1.2	3.64	0.7
HRM 134.0 (Smiths Bend)	3.38	0.7
HRM 122.8 (Phipps Bend)	2.09	0.2

TABLE 5.4-1

HOLSTON RIVER AQUATIC PLANT COMPOSITION AND BIOMASS FOR SELECTED LOCATIONS. HOLSTON RIVER.
JULY - AUGUST, 1977

				CHLOROPHYLLOUS[a]								TOTAL[b]							
Location	Species	% Composition by D.W.	% Composition by AFDW	g/m^2 Avg. D.W.	g/m^2 S.D. D.W.	g/m^2 Avg. AFDW	g/m^2 S.D. AFDW	kg/ha Avg. D.W.	kg/ha S.D. D.W.	kg/ha Avg. AFDW	kg/ha S.D. AFDW	g/m^2 Avg. D.W.	g/m^2 S.D. D.W.	g/m^2 Avg. AFDW	g/m^2 S.D. AFDW	kg/ha Avg. D.W.	kg/ha S.D. D.W.	kg/ha Avg. AFDW	kg/ha S.D. AFDW
HRM 117.6 Surgoinsville	H.d	84.80	81.70	371.38	119.81	206.25	54.55	3714	1198	2062	545	415.54	124.28	238.34	59.66	4155	1243	2283	597
	V.a	14.68	17.43																
	A.c	.60	.78																
	P.c	.01	.01																
	P.n	.01	.02																
	P.p	.05	.07																
HRM 119.4 Phipps Bend	H.d	76.68	74.30	226.78	216.06	144.36	130.01	2268	2161	1444	1300	245.59	234.99	156.50	141.11	2456	2350	1565	1411
	A.c	8.58	9.27																
	P.p	9.50	10.37																
	V.a	4.99	5.83																
	Moss	.24	.23																
HRM 119.7 Phipps Bend	V.a	99.56	99.58	311.75	134.26	198.02	91.57	3118	1343	1980	916	389.81	157.96	237.19	98.78	3897	1580	2372	988
	A.c	.40	.40																
	Moss	.04	.03																
HRM 120.6 Phipps Bend	P.n	95.90	95.48	159.01	37.72	109.30	29.07	1590	377	1093	291	186.92	61.58	127.92	39.55	1869	616	1279	396
	V.a	2.66	2.97																
	Moss	.53	.29																
	P.p	.75	.86																
	A.c	.02	.01																
	H.d	.15	.39																
HRM 134.2 Smiths Bend	Moss	86.73	69.66	64.21	69.34	20.54	20.19	642	693	205	202	66.66	73.58	22.52	23.63	666	736	225	236
	P.p	13.27	30.34																

TABLE 5.4-1 (Continued)

Location	Species	% Composition by D.W.	% Composition by AFDW	g/m^2 Avg. D.W.	g/m^2 S.D. D.W.	g/m^2 Avg. AFDW	g/m^2 S.D. AFDW	kg/ha Avg. D.W.	kg/ha S.D. D.W.	kg/ha Avg. AFDW	kg/ha S.D. AFDW	g/m^2 Avg. D.W.	g/m^2 S.D. D.W.	g/m^2 Avg. AFDW	g/m^2 S.D. AFDW	kg/ha Avg. D.W.	kg/ha S.D. D.W.	kg/ha Avg. AFDW	kg/ha S.D. AFDW
NFHRM 4.8 Cloud Ford	P.n	55.42	55.37	119.87	43.90	77.30	26.75	1199	439	773	268	127.80	48.34	83.27	29.78	1278	483	833	298
	P.p	22.41	23.37																
	H.d	20.81	19.80																
	V.a	1.34	1.44																
	Moss	.02	.02																
SFHRM 1.2 Ridgefield Bridge	P.p	96.54	95.92	169.13	22.14	109.32	11.38	1691	221	1093	116	195.80	22.00	126.06	10.53	1958	220	1260	105
	P.n	3.43	4.05																
	Moss	.03	.03																
SFHRM 39.6 Riverside	C-N	60.53	41.99	337.56	242.56	158.68	84.28	3376	2426	1587	843	344.76	241.20	163.20	86.80	3448	2412	1632	868
	A.c	36.36	54.55																
	Moss	2.42	2.75																
	P.c	.04	.06																
	Mix*	.64	1.14																

*Mix contains living plant material other than Anacharis

[a] Chlorophyllous includes "above ground" parts such as leaves and stems.

[b] Total includes "below ground" parts such as roots, rhizomes, tubers, stolens plus the chlorophyllous parts of the plants.

H.d - Heteranthera dubia
V.a - Vallisineria americana
A.c - Anacharis canadensis or Elodea
P.c - Potamogeton crispus
P.n - Potamogeton nodosus
P.p - Potamogeton pectinatus
C-N - Chara-Nitella

TABLE 5.4-2

DUNCAN'S MULTIPLE RANGE TEST FOR CHLOROPHYLLOUS
ASH-FREE DRY WEIGHT IN grams/0.25m^2. HOLSTON RIVER
JULY-AUGUST, 1977

S_m = 10.74

Shortest significant ranges

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
R	31.18	32.77	33.79	34.50	35.04	35.46	35.81	36.09

Results

Location	HRM 134.2	NFHRM 4.8	HRM 120.6	SFHRM 1.2	HRM 39.6	HRM 119.4	SFHRM 39.6	HRM 119.7	HRM 117.6
Means	5.13	19.32	27.32	27.33	32.92	36.09	46.42	49.50	51.56

*

* Any two means not underscored by the same line are significantly different at the .05 probability level.

S_m = Standard error of each mean

R = Shortest significant ranges

TABLE 5.4-3

AQUATIC PLANT PERCENT COVER. HOLSTON RIVER.
JULY - AUGUST, 1977

Segment	Description	River Miles	River Area in Hectares	Moss Cover in Hectares	Other Plant Cover in Hectares	% Moss Cover	% Other Plant Cover
1	Holston River Mile HRM 109.1 - HRM 141.2 (Interplant RR Bridge)	32.1	497.20	3.76	335.12	0.76	67.40
2	HRM 141.2 - South Fork River Mile (SFHRM) 5.6	6.6	69.36	0.00	47.71	0.00	68.79
2A	South Fork River Mile SFHRM 0.0 - 4.5	4.5	68.00		39.90		58.7
3	North Fork River Mile (NFHRM) 0.3 (Rotherwood Bridge)-NFHRM 39.1	38.8	341.10	5.16	94.21	1.51	27.62
3A	North Fork River Mile NFHRM 0.0 - 4.5	4.5	68.20		38.40		56.30
4	SFHRM 5.6 - SFHRM 8.2 (Ft. Patrick Henry Dam)	2.6	16.83	0.00	7.00	0.00	41.59
5	SFHRM 8.3 - SFHRM 49.9 (South Holston Dam)	41.6	185.92	0.20	97.65	0.11	52.52

TABLE 5.4-4

CHLOROPHYLLOUS BIOMASS ESTIMATES FOR ALL AQUATIC PLANTS EXCEPT THE MOSSES (SMITHS BEND SITE). HOLSTON RIVER. JULY - AUGUST, 1977

Segment	Description	River Miles	Total Plant Area in Hectares[a]	Avg. D.W. kg/ha	Avg. AFDW kg/ha	Total D.W. in Metric Tons[b]	Total AFDW in Metric Tons	Total River Area in Hectares	Avg. D.W. in Metric Tons Per Hectare of River	Avg. AFDW in Metric Tons Per Hectare of River
1	Holston River Mile (HRM) 109.1 - HRM 141.2 (Interplant RR Bridge)	32.1	139.42	2422	1433	337.68	199.79	497.20	0.68	0.40
2	HRM 141.2 - South Fork Holston River Mile (SFHRM) 5.6	6.6	27.84	2422	1433	67.43	39.89	69.36	0.97	0.58
2A	SFHRM 0.0 to SFHRM 4.5	4.5	24.90	2422	1433	60.31	35.68	68.00	0.89	0.52
3	North Fork Holston River Mile (NFHRM) 0.3 (Rotherwood Bridge) - NFHRM 39.1	38.8	28.53	2422	1433	69.10	40.88	341.10	0.20	0.12
3A	NFHRM 0.0 to NFHRM 4.5	4.5	13.80	2422	1433	33.42	19.78	68.20	0.49	0.29
4	SFHRM 5.6 - SFHRM 8.2 (Ft. Patrick Henry Dam)	2.6	1.60	2422	1433	3.88	2.29	16.83	0.23	0.14
5	SFHRM 8.3 - SFHRM 49.9 (South Holston Dam)	41.6	40.00	2422	1433	96.88	57.32	185.92	0.52	0.31

[a] Compressed area or area containing 100% plants.

[b] One metric ton = 1000 kg = 2205 lbs.

TABLE 5.4-5

TOTAL BIOMASS ESTIMATES FOR ALL AQUATIC PLANTS EXCEPT THE MOSSES (SMITHS BEND SITE).
HOLSTON RIVER. JULY - AUGUST, 1977

Segment	Description	River Miles	Total Plant Area in Hectares[a]	Avg. D.W. kg/ha	Avg. AFDW kg/ha	Total D.W. in Metric Tons[b]	Total AFDW in Metric Tons	Total River Area in Hectares	Avg. D.W. in Metric Tons Per Hectare of River	Avg. AFDW in Metric Tons Per Hectare of River
1	Holston River Mile (HRM) 109.1 - HRM 141.2 (Interplant RR Bridge)	32.1	139.42	2723	1603	379.64	223.49	497.2	0.76	0.45
2	HRM 141.2 - South Fork Holston River Mile (SFHRM) 5.6	6.6	27.84	2723	1603	75.81	44.63	69.36	1.09	0.64
2A	SFHRM 0.0 to SFHRM 4.5	4.5	24.90	2723	1603	67.80	39.91	68.0	1.00	0.59
3	North Fork Holston River Mile (NFHRM) 0.3 (Rotherwood Bridge - NFHRM 39.1	38.8	28.53	2723	1603	77.69	45.73	341.10	0.23	0.13
3A	NFHRM 0.0 to NFHRM 4.5	4.5	13.80	2723	1603	37.58	22.12	68.2	0.55	0.32
4	SFHRM 5.6 - SFHRM 8.2 (Ft. Patrick Henry Dam)	2.6	1.60	2723	1603	4.36	2.56	16.83	0.26	0.15
5	SFHRM 8.3 - SFHRM 49.9 (South Holston Dam)	41.6	40.00	2723	1603	108.92	64.12	185.92	0.59	0.34

[a] Compressed area or area containing 100% plants.

[b] One metric ton = 1000 kg = 2205 lbs.

TABLE 5.4-6

COMPARISON BETWEEN 1967 TVA AND 1969 EPA HOLSTON RIVER AQUATIC PLANT AVERAGE ASH-FREE DRY WEIGHTS AT SIMILARLY LOCATED STATIONS

TVA (1967) Holston River Mile	g/m^2	EPA (1969) Holston River Mile	g/m^2
132.8	345.0	131.4	40.4
118.0	329.4	118.4	No vascular plants
112.0	86.8	113.3	27.56
	$\bar{X} = 253.7$		$\bar{y} = 22.6$

TABLE 5.4-7

AQUATIC PLANT NUTRIENT CONTENT IN g/kg
DRY WEIGHT. HOLSTON RIVER. JULY - AUGUST, 1977

	Non-Chlorophyllous		Chlorophyllous		TOTAL (Chlorophyllous plus non-chlorophyllous	
Species	Total N	Total P	Total N	Total P	Total N	Total P
V. americana	17.39	2.98	23.32	3.06	20.35	3.02
H. dubia	13.46	2.47	20.91	2.61	17.81	2.55
P. pectinatus	19.89	1.81	24.26	2.43	22.67	2.20
P. nodosus	17.82	1.87	23.86	2.12	21.07	2.01
A. canadenses	17.62	2.18	25.70	2.24	22.47	2.22

TABLE 5.4-8

PERCENT AQUATIC PLANT NUTRIENT CONTENT[a] AT SELECTED LOCATIONS. HOLSTON RIVER. JULY - AUGUST, 1977

Location	Nitrogen	Phosphorus
SFHRM 1.2 Ridgefield Bridge	2.03	0.20
HRM 134.2 Smiths Bend	1.99	0.20
HRM 120.6, 119.7, 119.4 Phipps Bend	2.04	0.24
HRM 117.6 Surgoinsville	2.16	0.25

[a] For entire plant, chlorophyllous plus non-chlorophyllous D.W.

TABLE 5.4-9

AVERAGE TOTAL NITROGEN AND PHOSPHORUS IN kg/ha BOUND BY AQUATIC PLANTS AT SELECTED LOCATIONS. HOLSTON RIVER. JULY - AUGUST, 1977

Location	Nitrogen	Phosphorus
HRM 117.6 Surgoinsville	85.86	21.77
HRM 119.4 Phipps Bend	52.06	9.50
HRM 119.7 Phipps Bend	86.27	11.85
HRM 120.6 Phipps Bend	48.20	3.97
HRM 134.2 Smiths Bend	11.15	1.27
SFHRM 1.2 Ridgefield Bridge	46.31	4.62
SFHRM 39.6	55.03	3.06
NFHRM 4.8 Cloud Ford	29.33	2.92

TABLE 5.4-10

TOTAL NITROGEN BOUND BY AQUATIC PLANTS. HOLSTON RIVER. JULY-AUGUST, 1977

Segment	Description	Total Area in Hectares	Chlorophyllous				Non-Chlorophyllous				Total N in Metric Tons	Total N in Short Tons
			Moss		Other Plants		Moss		Other Plants			
			Avg. Total N in kg/ha	Total N in Metric Tons	Avg. Total N in kg/ha	Total N in Metric Tons	Avg. Total N in kg/ha	Total N in Metric Tons	Avg. Total N in kg/ha	Total N in Metric Tons		
1	Holston River Mile (HRM) 109.1-HRM 141.2 (Interplant Bridge)	139.42	10.66	1.49	51.69	7.21	0.49	0.07	5.89	0.82	9.59	10.57
2	HRM 141.2-South Fork (Holston) River Mile (SFHRM) 5.6	27.84	10.66	0.30	51.69	1.44	0.49	0.01	5.89	0.16	1.91	2.11
3	North Fork (Holston) River Mile (NFHRM) 0.3 (Rotherwood Bridge)-NFHRM 39.1	28.53	10.66	0.30	51.69	1.47	0.49	0.01	5.89	0.17	1.95	2.15
4	SFHRM 5.6-SFHRM 8.2 (Ft. Patrick Henry Dam)	1.60	10.66	0.02	51.69	0.08	0.49	7.8×10^{-4}	5.89	0.01	0.11	0.12
5	SFHRM 8.3 - SFHRM 49.9 (South Holston Dam)	40.00	10.66	0.43	51.69	2.07	0.49	0.02	5.89	0.24	2.76	3.04

TABLE 5.4-11

TOTAL PHOSPHORUS BOUND BY AQUATIC PLANTS. HOLSTON RIVER. JULY-AUGUST, 1977

Segment	Description	Total Area in Hectares	Chlorophyllous				Non-Chlorophyllous				Total P in Metric Tons	Total P in Short Tons
			Moss		Other Plants		Moss		Other Plants			
			Avg. Total P in kg/ha	Total P in Metric Tons	Avg. Total P in kg/ha	Total P in Metric Tons	Avg. Total P in kg/ha	Total P in Metric Tons	Avg. Total P in kg/ha	Total P in Metric Tons		
1	Holston River Mile (HRM) 109. - HRM 141.2 (Interplant Bridge)	139.42	1.23	0.17	5.50	0.77	0.04	5.58×10^{-3}	2.75	0.38	1.33	1.47
2	HRM 141.2 - South Fork (Holston) River Mile (SFHRM) 5.6	27.84	1.23	0.03	5.50	0.15	0.04	1.11×10^{-3}	2.75	0.08	0.26	0.29
3	North Fork (Holston) River Mile (NFHRM) 0.3 (Rotherwood Bridge)-NFHRM 39.1	28.53	1.23	0.04	5.50	0.16	0.04	1.14×10^{-3}	2.75	0.08	0.28	0.31
4	SFHRM 5.6-SFHRM 8.2 (Ft. Patrick Henry Dam)	1.60	1.23	1.97×10^{-3}	5.50	8.80×10^{-3}	0.04	6.40×10^{-5}	2.75	4.40×10^{-3}	0.02	0.02
5	SFHRM 8.3-SFHRM 49.9 (South Holston Dam)	40.00	1.23	0.05	5.50	0.22	0.04	1.60×10^{-3}	2.75	0.11	0.38	0.42

TABLE 5.4-12

LEAF INDEX[a] FOR HOLSTON RIVER. JULY-AUGUST, 1977

Site	Ave. Photosynthetic Surface Area in m^2/m^2
Cox Island, HRM 117.6	0.60
Phipps Bend, HRM 119.4	0.34
Phipps Bend, HRM 120.6	0.17
Phipps Bend, HRM 119.7	1.05
Smiths Bend, HRM 134.2	0.01
Ridgefield Br., SFHRM 1.2	0.25
North Fork, NFHRM 4.8	0.15
Total =	2.58
Ave. =	0.37

[a] Based on Predominant Plant Species:

Heteranthera dubia
Potamogeton nodosus
Potamogeton pectinatus
Vallisneria americana

TABLE 5.5-1

AVERAGE CONCENTRATIONS OF NITROGEN FRACTIONS AT VARIOUS STATIONS ON THE HOLSTON RIVER DURING FLUCTUATING RIVER FLOW JULY, 1977

Station	Nitrogen Concentrations mg/L			
	TKN	NH_3-N	NO_2-NO_3	Total N
NFHRM 0.6	.177	.033	.054	.231
SFHRM 7.2	.202	.045	.597	.799
HRM 136	.430	.20	.569	.999
HRM 126	.472	.215	.737	1.109
HRM 120	.526	.293	.698	1.224

TABLE 5.5-2

AVERAGE CONCENTRATIONS OF NITROGEN FRACTIONS AT VARIOUS STATIONS ON THE HOLSTON RIVER DURING STEADY STATE CONDITIONS JULY, 1977

Station	Nitrogen Concentrations in mg/L			
	TKN	NH_3-N	NO_2-NO_3	Total N
NFHRM 0.6	.21	.04	.06	.270
SFHRM 7.2	.20	.05	.60	.800
HRM 136	.54	.29	.53	1.07
HRM 126	.61	.28	.85	1.46
HRM 120	.67	.38	.81	1.48

TABLE 5.5-3

COMPARISON OF NITROGEN VALUES BETWEEN HYPOTHETICAL STATION X AND EXPERIMENTAL STATIONS USING ONE-WAY ANALYSIS OF VARIANCE (.05 PROBABILITY LEVEL)

	STEADY			FLUCTUATING		
Station	TKN	NH_3	NH_3+NO_2	TKN	NH_3	NH_3+NO_2
120	+	0	-	-	-	-
126	+	+	-	0	0	0
136	+	0	+	0	0	0

Legend:

+ = Station X is significantly greater than

- = Station X is significantly less than

0 = No significant difference

TABLE 5.5-4
CONCENTRATIONS OF PHOSPHORUS AT VARIOUS STATIONS ON THE HOLSTON RIVER
JULY, 1977

Station	Average Concentration in mg/L	
	Total Phosphorus mg/L	Dissolved Phosphorus mg/L
NFHRM 0.6	0.04	0.02
SFHRM 7.2	0.04	0.02
HRM 136	0.14	--
HRM 126	0.20	0.08
HRM 120	0.20	0.10

TABLE 5.7-1
DIEL DISSOLVED OXYGEN AND WATER TEMPERATURE VALUES ASSOCIATED WITH DYE PEAK. HOLSTON RIVER. JULY 23-24, 1977.

Data	River Mile	Time	Water Temp. °C	DO mg/L	% DO[a] sat.
23 July	141.3	1100	24.0	4.5	56
	139.2	1345	25.0	5.6	70
	136.2	2050	27.0	7.2	95
24 July	131.7	0335	25.0	4.3	54
	128.5	0845	25.0	5.1	64
	126.6	1300	27.0	6.6	87
	121.6	2245	26.5	5.1	66
25 July	118.4	0340	23.0	4.9	65

[a] Corrected for local elevation and barometric pressure.

TABLE 5.7-2

COMMUNITY GROSS PRIMARY PRODUCTION (GPP) AND RESPIRATION (R) IN g/m^2/DAY. HOLSTON RIVER. JULY-AUGUST, 1977

Station	K	GPP	R
HRM 136.1	0.48	14.80	18.00
HRM 134.2	1.18	11.00	18.20

TABLE 5.7-3

PRIMARY PRODUCTION STUDY
DIEL DATA FOR DO, TEMPERATURE, AND PERCENT DO SATURATION. HOLSTON RIVER.
JULY 23-24, 1977

	Left Side River[a]		Mid River		Right Side River		Avg. for Station		
Time	DO mg/L	Temp °C	DO mg/L	Temp. °C	DO mg/L	Temp °C	DO mg/L	Temp °C	% DO Sat.[b]
HRM 136.1									
1800	9.6	29.5	9.2	30.5	9.2	29.0	9.3	29.7	128
2100	8.6	29.0	7.6	29.0	7.4	28.5	7.9	28.8	107
2400	6.4	27.0	5.9	27.5	5.8	27.0	6.0	27.2	79
0300	5.4	27.0	5.2	26.0	4.8	27.0	5.1	26.7	66
0800	4.2	27.0	4.0	25.0	4.0	25.0	4.1	25.7	52
0900	3.6	27.0	3.4	25.0	3.4	25.0	3.5	25.7	45
1200	5.5	27.0	6.0	25.0	5.8	25.0	5.8	25.7	74
1500	8.0	27.0	7.8	25.0	7.4	25.0	7.7	25.7	98
1800	8.5	27.0	8.6	25.0	8.0	25.0	8.4	25.7	107
HRM 134.2									
2300	6.1	27.0	6.4	27.0	5.8	27.0	6.1	27.0	80
0200	5.2	27.0	5.0	27.0	4.9	27.0	5.0	27.0	65
0500	4.2	27.0	4.4	27.0	4.2	27.0	4.3	27.0	56
0800	3.8	27.0	3.6	27.0	3.4	27.0	3.6	27.0	47
1100	5.7	24.8	5.8	24.8	6.2	25.0	5.9	24.9	74
1300	6.0	24.8	6.2	24.8	6.5	25.0	6.2	24.9	78
1700	8.5	25.8	9.1	25.8	9.2	26.0	8.9	25.9	114
2000	7.4	25.3	7.8	25.8	7.6	25.8	7.6	25.6	97
2300	5.2	26.0	5.6	26.0	5.4	26.0	5.4	26.0	69

[a] Looking downstream.

[b] Corrected for local elevation and barometric pressure.

TABLE 5.7-4

COMMUNITY GROSS PRIMARY PRODUCTION (GPP)
AND RESPIRATION (R) IN g/m^2/DAY. HOLSTON RIVER.
JULY-AUGUST, 1977

Date	Reach	K	GPP	R
July 23-24	HRM 141.3 to 126.6	0.60	7.70	9.60
July 24-25	HRM 131.7 to 118.4	0.53	2.50	4.70

TABLE 5.8-1

SOLAR RADIATION, HOLSTON RIVER.
JULY-AUGUST, 1977

Run No.	Date	Total Langleys/Day	Total Langleys/Run @ Surface	Langleys/Run @ Bottom[a]	Langleys/ hr./Run	Length of run in hrs.
1	7/27	609.2	498.5	59.8	17.1	3.5
2	7/28	568.7	138.5	16.6	11.1	1.5
3	7/29	138.5	96.9	11.6	2.6	4.4
4	7/29	138.5	13.9	1.7	1.1	1.5

[a] 12% of light available at surface

TABLE 5.8-2

RESPIRATION, HOLSTON RIVER, JULY, 1977

Run No.	Avg. Temp. °C	Respiration/hr. (g O_2/m^2/hr.)	Respiration/Day (g. O_2/m^2/24 hrs.)	Respiration/Day @20°C	Habitat type
1	24	.1710	4.104	3.19	Substrate periphyton
2	23	.2304	5.5296	4.55	Rooted plants w/periphyton and substrate periphyton
3	23	.3721	8.9304	7.39	"
4	22.6	.4454	10.6896	9.07	"
Average Run 2,3, 4	23.2	.35	8.4	6.87	"

TABLE 5.8-3

GROSS PRIMARY PRODUCTION, HOLSTON RIVER, JULY, 1977

Run No.	Avg. Temp. °C	NPP[b] ($g\ O_2/m^2/hr.$)	Avg. Respiration ($g\ O_2/m^2/day$)	GPP[c] ($g\ O_2/m^2/hr.$)	GPP ($g\ O_2/m^2/day$)	GPP @20°C	Habitat Type
1	24.0	0.0125	0.1710[a]	0.1835	2.4773	1.93	Substrate periphyton
2	23.0	0.2022	0.35	0.55	7.43	6.15	Rooted plants w/periphyton and substrate periphyton
3	23.0	0.2497	0.35	0.59	7.97	6.60	"
4A	22.6°	-0.1585	0.35	0.20	2.7	2.29	"
4B	22.6°	-0.0157	0.35	0.34	4.59	3.90	"
Avg. for Runs 2,3,4A&B	22.8	0.16	0.35	0.42	5.67	4.74	

[a] Run 1 respiration is not average but represents actual respiration monitored for the run. Average respiration was not used in the calculation of GPP for this run as it was for Runs 2, 3, and 4 because plants in Run 1 consisted only of substrate periphyton.

[b] NPP - Net Primary Production

[c] GPP - Gross Primary Production

TABLE 5.8-4

PLANTS SPECIATION AND BIOMASS FOR
BENTHIC RESPIRATION STUDY. HOLSTON RIVER.
JULY, 1977

Run#	Chamber	Vegetation Type or Species	grams/.64m^2 Dry Wt.	g/m^2	grams/.64m^2 Ash-free Dry Wt.	g/m^2
1	clear	Periphytic	1.989*		0.362*	
1	dark	Periphytic	1.341*		0.265*	
2	clear	*Potamogeton crispus*	5.527		3.539	
		Potamogeton pectinatus	1.088		0.777	
		Anacharis canandensis	0.016		0.006	
		Mosses	0.210		0.142	
		Nitella sp.	0.027		0.023	
		Periphytic	0.483		0.086	
		TOTAL	7.35	(11.48)	4.57	(7.14)
2	dark	*Potamogeton crispus*	0.005		0.004	
		P. nodosus	10.429		7.055	
		P. pectinatus	0.877		0.656	
		Vallisneria americana	3.786		2.758	
		Mosses	0.462		0.286	
		Periphytic	0.270		0.065	
		TOTAL	12.04	(18.81)	10.82	(16.91)
3	clear	Periphytic (on rocks)	0.406*		0.225*	
		P. pectinatus	2.716		1.928	
		P. crispus	1.499		1.071	
		Vallisneria americana	25.149		13.730	
		Mosses	0.857		0.449	
		Periphytic (on plants)	0.359		0.101	
		TOTAL	30.99	(48.42)	17.50	(27.34)

TABLE 5.8-4 (Continued)

3	dark	Periphytic (on rocks)	0.543		0.192	
		P. crispus	12.873		8.751	
		P. pectinatus	3.672		2.630	
		Cladophora sp.	0.057		0.031	
		Anacharis canandensis	0.158		0.108	
		Mosses	2.115		1.161	
		Periphytic (on plants)	0.218		0.053	
		TOTAL	19.64	(30.69)	12.93	(20.20)
4	light	_P. pectinatus_	11.160		7.495	
		P. crispus	2.881		2.113	
		P. nodosus	4.908		3.531	
		Mosses	0.225		0.149	
		Periphytic	0.391		0.058	
		TOTAL	19.57	(30.58)	33.35	(52.11)
4	light	_P. pectinatus_	0.511		0.368	
		p. crispus	1.214		0.902	
		Vallisneria americana	11.599		7.615	
		Mosses	1.069		0.608	
		Periphytic	0.325		0.033	
		TOTAL	14.72	(23.00)	9.53	(14.89)
4	dark	_p. pectinatus_	3.394		2.357	
		Vallisneria americana	11.978		7.851	
		Mosses	1.084		0.634	
		Periphytic	0.104		0.031	
		TOTAL	16.56	(25.88)	10.87	(16.98)

*Indicates periphytic growth from rocky substrate as opposed to periphytic growth on rooted aquatics.

TABLE 5.8-5

COMMUNITY RESPIRATION RATES UNDER SOD CHAMBERS LOCATED AT HRM 121.6. HOLSTON RIVER. JULY 27-29, 1977

Run 1	4.104 g O_2/m^2/day @24°C	3.15 g O_2/m^2/day @20°C
Run 2	5.5296 g O_2/m^2/day @23°C	4.55 g O_2/m^2/day @20°C
Run 3	8.9304 g O_2/m^2/day @23°C	7.39 g O_2/m^2/day @20°C
Run 4	10.6896 g O_2/m^2/day @22.6°C	9.07 g O_2/m^2/day @20°C
Average	7.31 g O_2/m^2/day @23.15°C	5.99 g O_2/m^2/day @20°C

TABLE 5.10-1

MEAN DISSOLVED OXYGEN LEVELS (mg/L) AT CHEROKEE RESERVOIR STATIONS. JULY , 1977

Depth (Meters)	Station					
	92	86	75	67	59-60	55
Surface	6.1	5.8	5.9	6.8	6.6	7.8
1	6.0	5.7	5.6			
2	6.0	5.0				
3	5.9	5.2				
4	5.9	4.8				
5	5.2	4.6		5.4	6.0	6.7
6	5.0	4.1	4.9	5.3		
7		4.0	4.2			
8		4.2	2.2			
9		3.9		4.4		
10		3.0			5.7	6.0
11		1.7			4.3	3.9
12			1.8	0.8	3.8	1.0
13			0	0	1.6	0.2
14					0	0
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						

TABLE 5.10-2

MEAN TEMPERATURE LEVELS (^{o}C) AT CHEROKEE RESERVOIR STATIONS. JULY , 1977

Depth (Meter)	Stations					
	92	86	75	67	59-60	55
Surface	26	27	27	28	28.5	29
1	26	27	27			
2	26	27	27	28	28	28
3	26	27	27			--
4	26	27	27	28	28	28
5	26	27	27			--
6	25	27	27	27.5	27.5	27.5
7		27	27			--
8		27	27	27	27.5	27.5
9		27	27			--
10		26.5	26.5	27	27	27
11		26	26			26.5
12		26	26	27.5	26.5	26
13			25.5			25.5
14			25	26.5	26	25.5
15			25			25
16			24.5	26	25.5	24.5
17			24.5			24
18			24	25	25	23.5
19			23.5			23.5
20				25.5	24.5	23
21						23
22				25	24	23
23				24.5		22.5
24				24	23	22
25				24		22
26				23.5	22.5	21.5
27				23.5	22	
28				23		
29				22.5		
30				22.5		
31				22		

TABLE 5.10-3
CHEROKEE RESERVOIR 1977 1% LIGHT EXTINCTION DEPTH (LED) IN METERS, AND 1977 AND 1973 SECCHI DISK (SD) TRANSPARENCY DEPTH IN METERS

	STATIONS								
	53	55	57	59-60	67	GCE	75	86	92
LED		6.8		5.8	5.3	5.8	4	2.8	1.8
1977-SD		2		1.5	2	1.5	2	1	0.6
1973-SD	1.7		1.8	1.1		1.3	1.3	1.5	1.2

TABLE 5.10-4

MEAN EUPHOTIC ZONE NITROGEN AND PHOSPHORUS LEVELS IN mg/L. NITROGEN TO PHOSPHORUS RATIOS, GROWTH LIMITING NUTRIENT AND PREDICTED MAXIMUM DRY WEIGHT (mg/L) AT STATIONS IN CHEROKEE RESERVOIR.
JULY, 1977

Station	Mean Inorganic Nitrogen	Mean Total Nitrogen	Mean Total Phosphorus	Inorganic N: P ratio	Limiting Nutrient	Total N: P ratio	Limiting Nutrient	Predicted Dry Weight
55	0.07	0.28	<0.01	07:1	N	28:1	P	<4.3
59-60	0.13	0.26	<0.01	13:1	P	26:1	P	<4.3
67	0.14	0.36	<0.01	14:1	P	36:1	P	<4.3
75	0.28	0.51	0.05	5.6:1	N	10.2:1	N-P	21.5
86	0.45	0.69	0.07	6.4:1	N	9.9:1	N-P	26.2
92	0.90	1.21	0.12	7.5:1	N	10.1:1	N-P	45.9

TABLE 5.10-5

MEAN NITROGEN (N) AND PHOSPHORUS (P) LEVELS IN mg/L FROM DEPTHS GREATER THAN THE EUPHOTIC ZONE , NITROGEN TO PHOSPHORUS RATIOS, GROWTH LIMITING NUTRIENT, AND PREDICTED DRY WEIGHT

Station	Mean Inorganic Nitrogen	Mean Total Nitrogen	Mean Total Phosphorus	Inorganic N: P ratio	Limiting Nutrient	Total N: P ratio	Limiting Nutrient	Predicted Dry Weight
55	0.05	0.27	< 0.01	5:1	N	27:1	P	4.3
59-60	0.67	0.86	0.01	67:1	P	86:1	P	4.3
67	0.74	0.79	0.05	14.8:1	P	15.8:1	P	21.5
75	0.75	0.94	0.08	9.4:1	N	11.8:1	P	34.4
86	0.57	0.69	0.12	4.8:1	N	5.8:1	P	26.2
92	0.95	1.16	0.13	7.3:1	N	8.9:1	N	44.1

TABLE 5.10-6

CHEROKEE RESERVOIR CHLOROPHYLL a LEVELS IN mg/m^3. JULY , 1977

	Stations Upstream of US25E Bridge			Stations Downstream of US25E Bridge					
Depth in Meters	92	86	Upstream Avg.	75	67	59-60	55	Downstream Avg.	Overall Avg.
.1				17.16	6.99				
1						1.76			
3	1.82								
4		6.1				6.86			
5				8.39					
7							7.28		
20					0.83				
Avg.			3.96					8.07	6.01

TABLE 5.10-7

NUTRIENT ADDITIONS TO FIRST CHEROKEE RESERVOIR ALGAL ASSAY

Treatments:

1. Reference medium
2. Sample water (control)
3. Sample water plus 0.03 mg phosphorus per liter.
4. Sample water plus 0.06 mg phosphorus per liter.
5. Sample water plus 0.12 mg phosphorus per liter.
6. Sample water plus 0.3 mg nitrogen per liter.
7. Sample water plus 0.6 mg nitrogen per liter.
8. Sample water plus 1.2 mg nitrogen per liter.

TABLE 5.10-8

PREDICTED AND ACTUAL YIELDS OF SELANASTRUM IN mg/L. FIRST CHEROKEE RESERVOIR ALGAL ASSAY.

	Control[a]	Nitrogen			Phosphorus		
		.3	.6	1.2	.03	.06	.12
predicted yield[b]	9.9	20.9	32.3	55.1	30.1	43.0	68.8
actual yield	1.2	0.9	1.4	2.4	1.5	1.6	1.4
N/P ratio	6.5:1	14:1	21.5:1	36.5:1	3.7:1	26:1	16:1

[a] Contains .26 mg N/L and .04 mg P/1.

[b] water containing >.01 mg/L orthophosphorus and having sufficient other growth nutrients will yield 430 mg dry wt. Selanastrum (±.20) per mg P/L. Each mg/L inorganic nitrogen will yield 38 mg dry wt. Selanastrum (±.20) in water with sufficient other growth nutrients.

TABLE 5.10-9

NUTRIENT ADDITIONS. SECOND CHEROKEE RESERVOIR ALGAL ASSAY

Treatments:

1. Reference medium
2. Sample water (control)
3. Sample water plus 1.0 mg nitrogen and 1.0 mg EDTA per liter.
4. Sample water plus 0.05 mg phosphorus plus 1.0 mg EDTA per liter.
5. Sample water plus 0.05 mg phosphorus plus 1.0 mg nitrogen per liter.
6. Sample water plus 0.05 mg phosphorus plus 1.0 mg nitrogen plus 1.0 mg EDTA per liter.
7. Sample water plus 1.0 ml algal assay media.
8. Sample water plus 1.0 ml micronutrient solution.

TABLE 5.10-10

PREDICTED AND ACTUAL MAXIMUM YIELDS OF SELANASTRUM IN mg/L. CHEROKEE RESERVOIR SECOND ALGAL ASSAY.

	control[a]	+ 1 mg N & 1 mg EDTA	+ .05 mg P + 1 mg EDTA	+ .05 mg P + 1.0 mg N	+ .05 mg P + 1 mg N + 1 mg EDTA	+ 1 ml Algal Assay Media	+ 1 ml Micro-nutrient solution
predicted yield[b]	9.9	17.2	9.9	38.7	38.7	9.9	9.9
Actual yield	0.07	0.14	2.6	0.69	11.0	0.28	0.28
N/P ratio	6.5:1	31.5:1	2.9:1	14:1	14:1	6.5:1	6.5:1

[a] Lake water control contained .26 mg N/L and .04 mg P/liter.

[b] Water containing >.01 mg/L orthophosphorus and having sufficient other growth nutrients will yield 430 mg dry wt Selanastrum (±.20) per mg P/L.
Each mg/L inorganic nitrogen will yield 38 mg dry wt Selanastrum in water containing sufficient other growth nutrients.

TABLE 5.10-11

PLASMA EMISSION SPECTROSCOPIC METAL SCAN (mg/L)

Al	0.15	Mn	<0.005
As	<0.05	Mo	<0.005
B	0.011	Ni	<0.005
Ba	0.015	Pb	<0.05
Be	<0.005	Sb	<0.010
Ca	12.0	Se	<0.050
Cd	<0.005	Sn	<0.050
Co	<0.005	Sr	0.065
Cr	<0.005	Ti	<0.005
Cu	<0.005	V	<0.005
Fe	0.005	Y	<0.005
Hg	<0.010	Zn	<0.005
Mg	1.6		

TABLE 5.10-12

CHEMICAL ANALYSES AND NITROGEN:PHOSPHORUS RATIO OF CHEROKEE RESERVOIR COMPOSITE ALGAL ASSAY WATER SAMPLES COLLECTED AUGUST 3, 1977

Treatment	NO_2-NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)	N:P Ratio
Raw lake water	.26	.07	.28	.54	.05	10.8:1
Autoclaved & filtered	.23	.02	.36	.59	.04	14.8:1

TABLE 5.10-13

PARAMATER LEVELS FROM CHEROKEE RESERVOIR AUGUST 1973 NATIONAL EUTROPHICATION LAKE SURVEY AND JULY 1977 SURVEY[a]

Year	Median Total Phosphorus (mg/L)	Median Ortho-Phosphorus[b] (mg/L)	Median Inorganic Nitrogen (mg/L)	500 Mean Secchi disc	Mean Chlorophyll a (mg/m^3)	15 Minus Minimum Dissolved Oxygen (mg/L)
1973	.074	.042	.94	445	14.8	13.8
1977	.020	.020	.29	441	6.0	15.0

a - Based upon U.S. EPA working paper 445, 1976.

b - Total dissolved phosphorus substituted for orthophosphorus in 1977.

TABLE 5.10-14

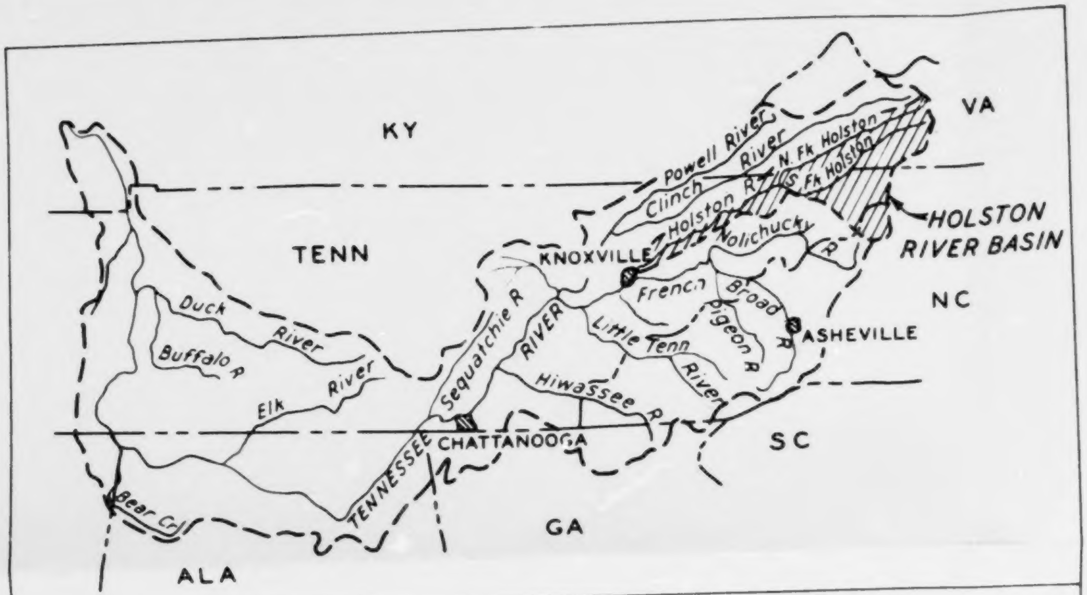
PERCENT OF 16 TVA RESERVOIR 1973 VALUES EXCEEDING CHEROKEE RESERVOIR AUGUST, 1973 AND JULY 1977 PARAMETER VALUES AND THE TROPHIC INDEX NUMBER FOR CHEROKEE RESERVOIR [a]

Year	Median Total Phosphorus mg/L	Median Dissolved Phosphorus[b] mg/L	Median Inorganic Nitrogen mg/L	Mean Chlorophyll a (mg/m^3)	500 minus Secchi Disk (inches)	15 Minus Dissolved Oxygen Level (mg/L)	Trophic Index
1973	19	19	6		62	50	162
1977	81	69	75	56	69	13	363

[a] Based upon U.S. EPA Working paper 445, 1976.

[b] Total dissolved phosphorus substituted for orthophosphorus.

FIGURES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French Broad R
NC
ASHEVILLE
Pigeon R
Little Tenn River
Duck River
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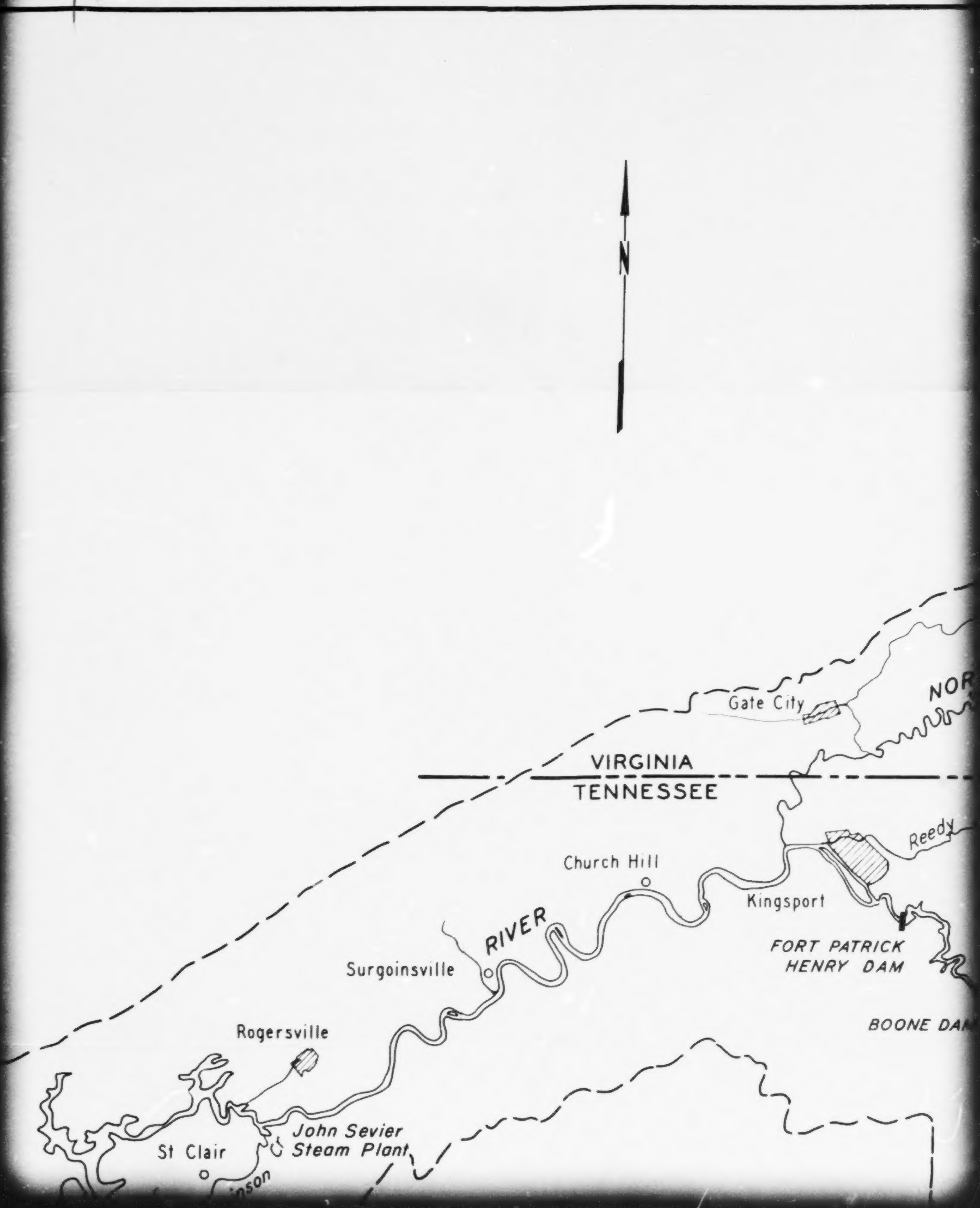
Sequatchie R
RIVER
Hiwassee R
SC
TENNESSEE
CHATTANOOGA
Bear Cr
GA
ALA

KEY MAP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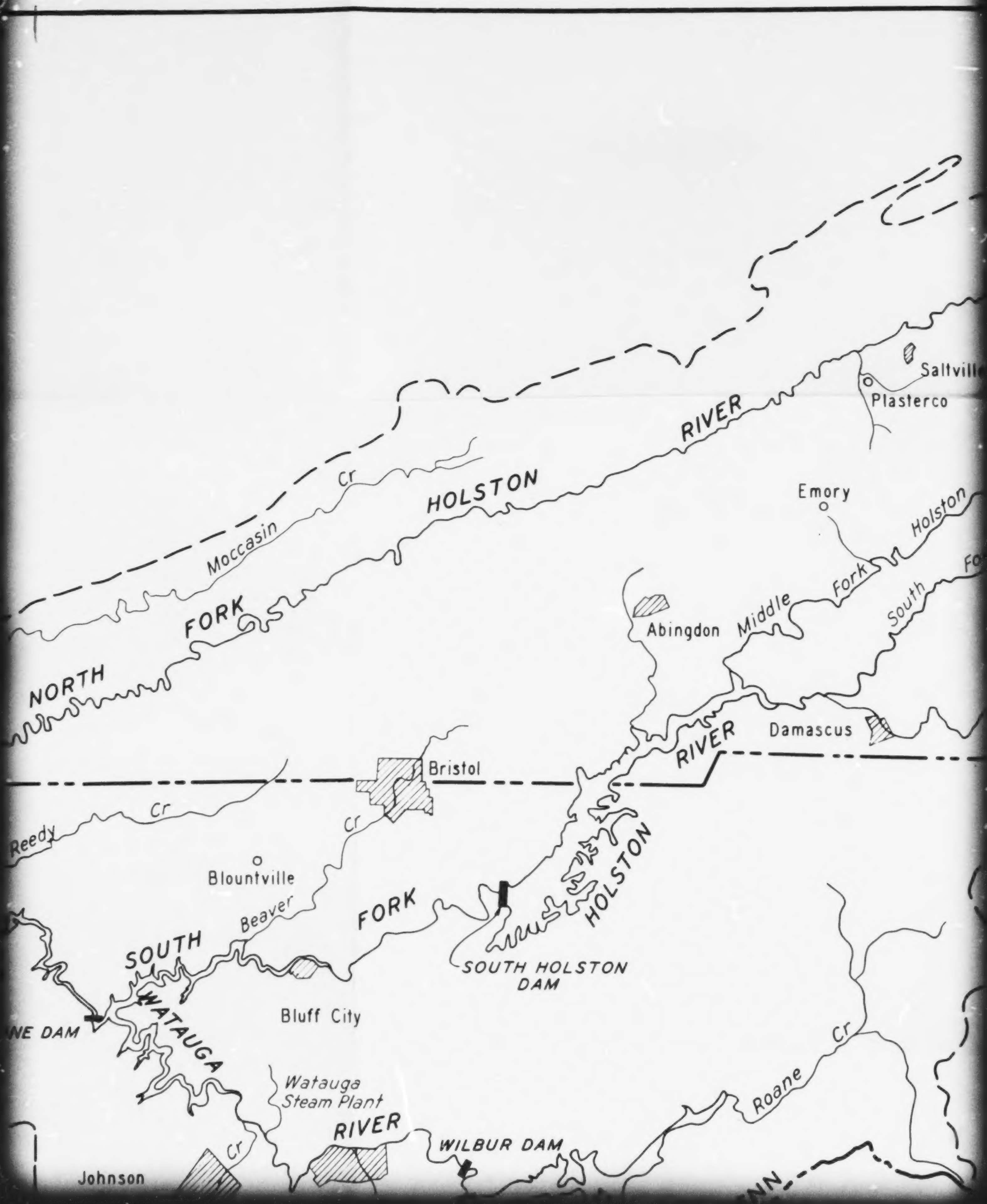

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RIVER
Bristol
Reedy
Cr
Cr
Blountville
Beaver
FORK
HOLSTON
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Roane
Cr
Cr
Johnson
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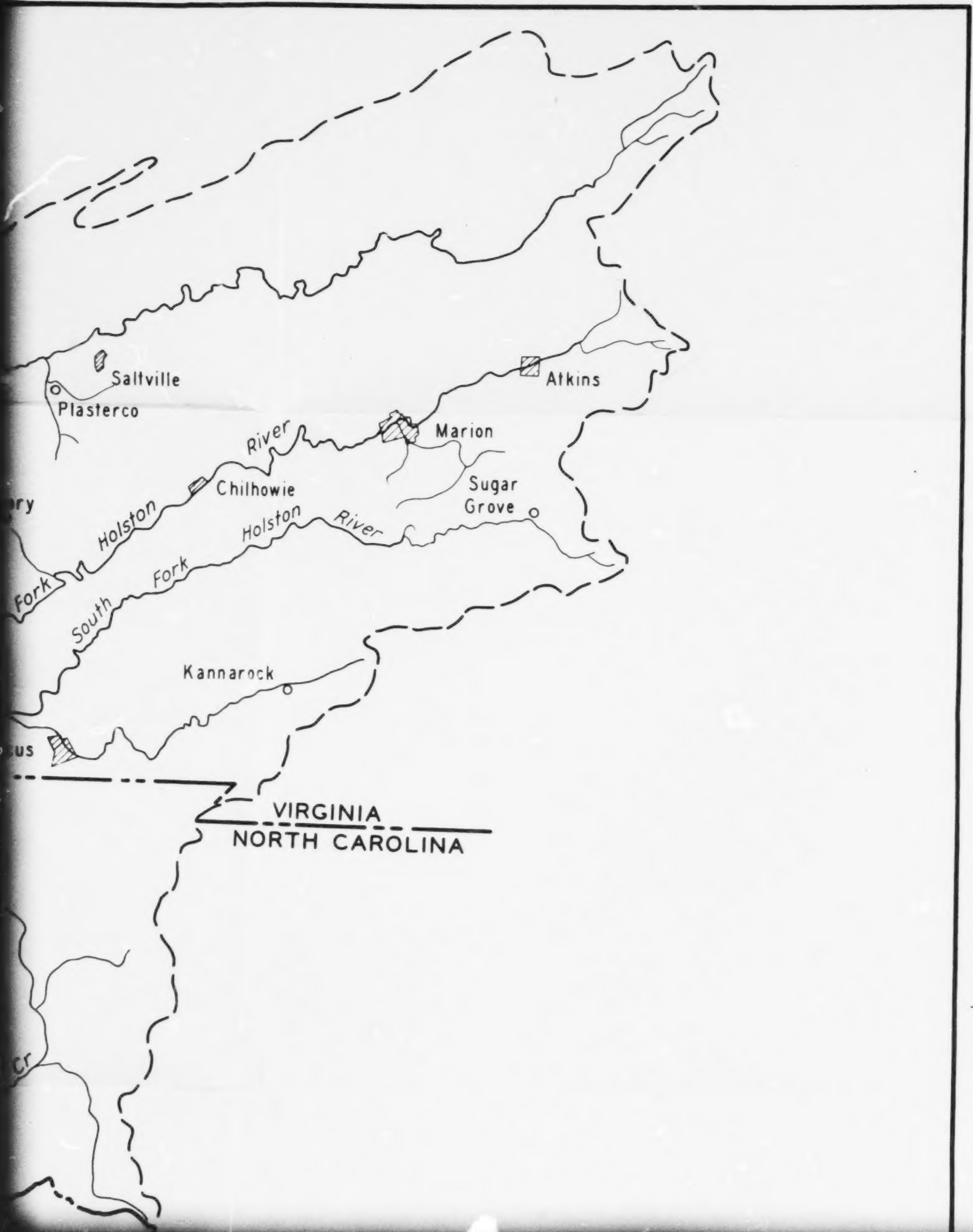
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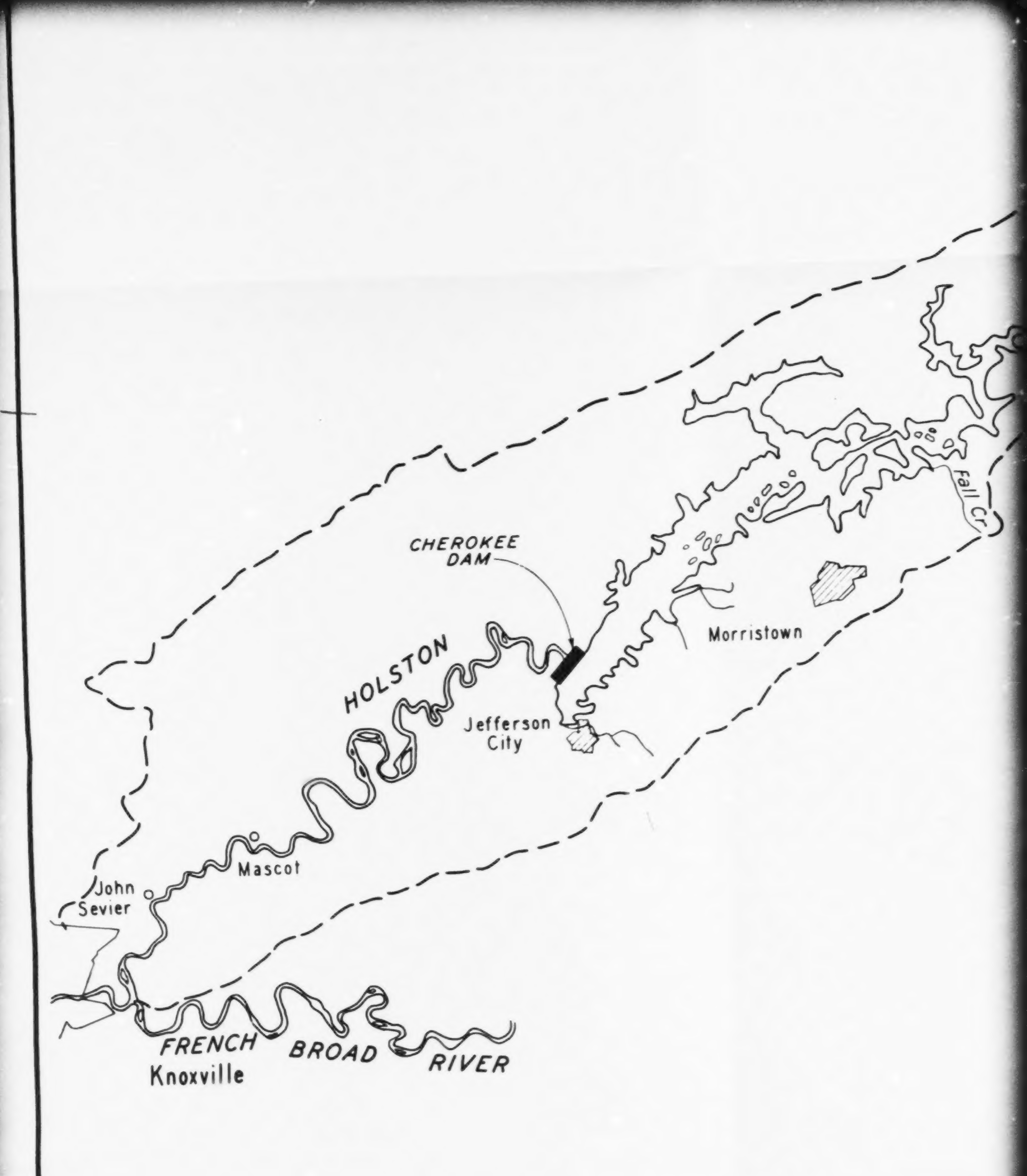
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Morristown
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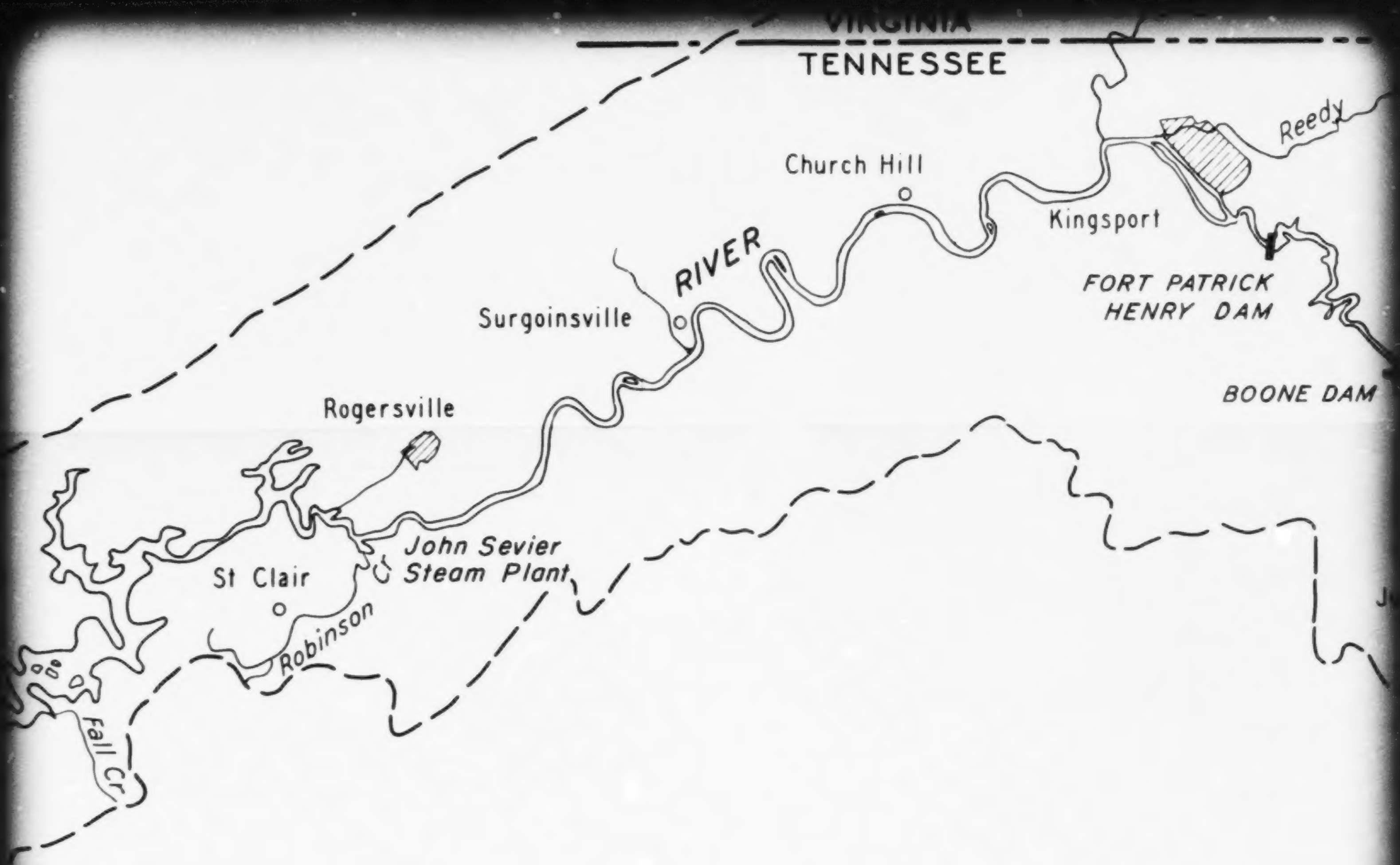
John Sevier
FRENCH BROAD RIVER
Knoxville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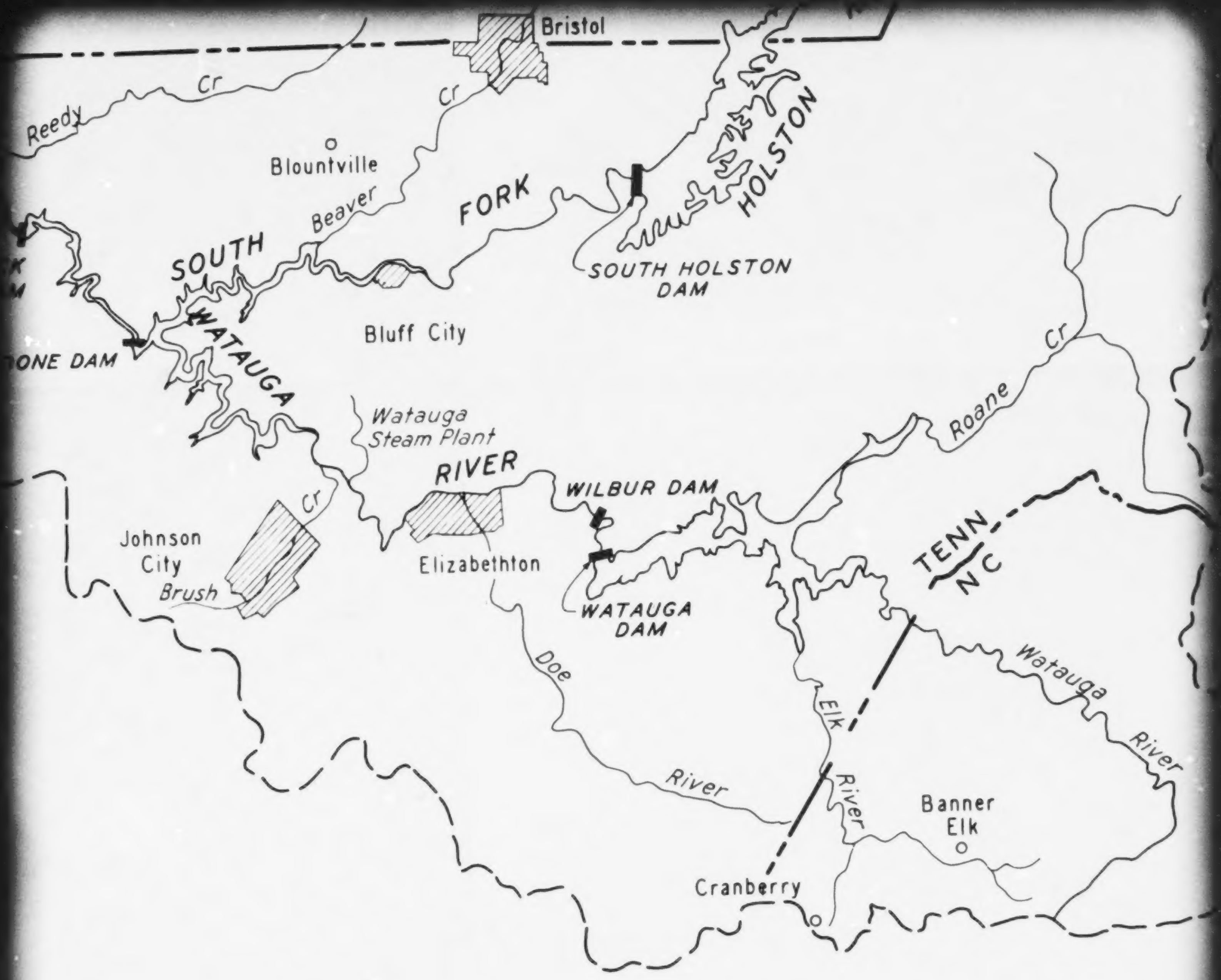
Reedy
Church Hill
Kingsport
FORT PATRICK HENRY DAM
RIVER
Surgoinsville
BOONE DAM
Rogersville
John Sevier Steam Plant
St Clair
Robinson Cr
Fall Cr


Bristol
Reedy
Cr
Cr
Blountville
Beaver
FORK
SOUTH
HOLSTON
SOUTH HOLSTON DAM
ONE DAM
WATAUGA
Bluff City
Watauga Steam Plant
RIVER
Roane
Cr
WILBUR DAM
Cr
Johnson City
Brush
Elizabethton
WATAUGA DAM
TENN
NC
Doe
River
Elk
River
Watauga
River
Banner Elk
Cranberry

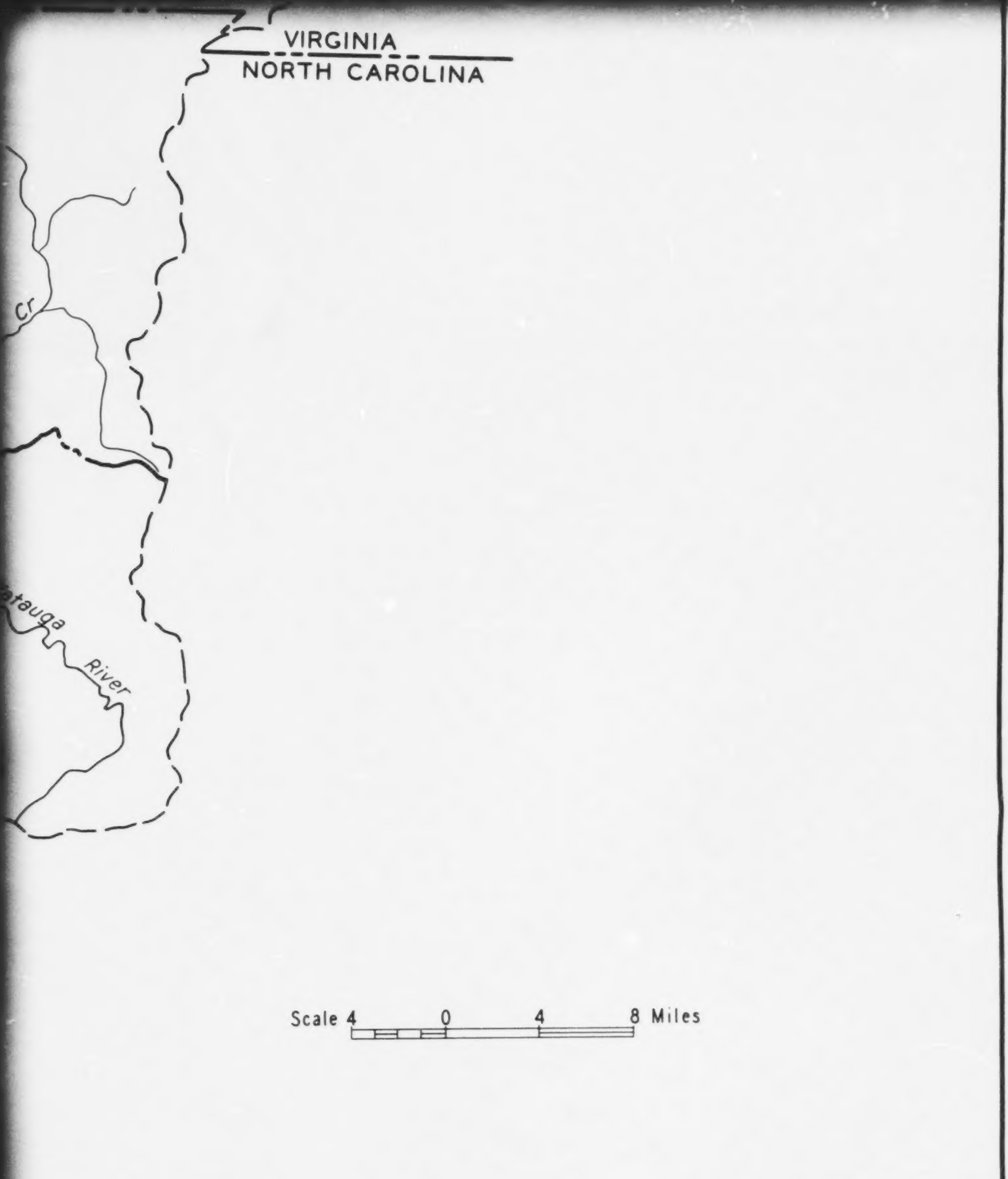

VIRGINIA
NORTH CAROLINA
Cr
atauga River
Scale 4 0 4 8 Miles

FIGURE 2.2

HOLSTON RIVER GRADIENT

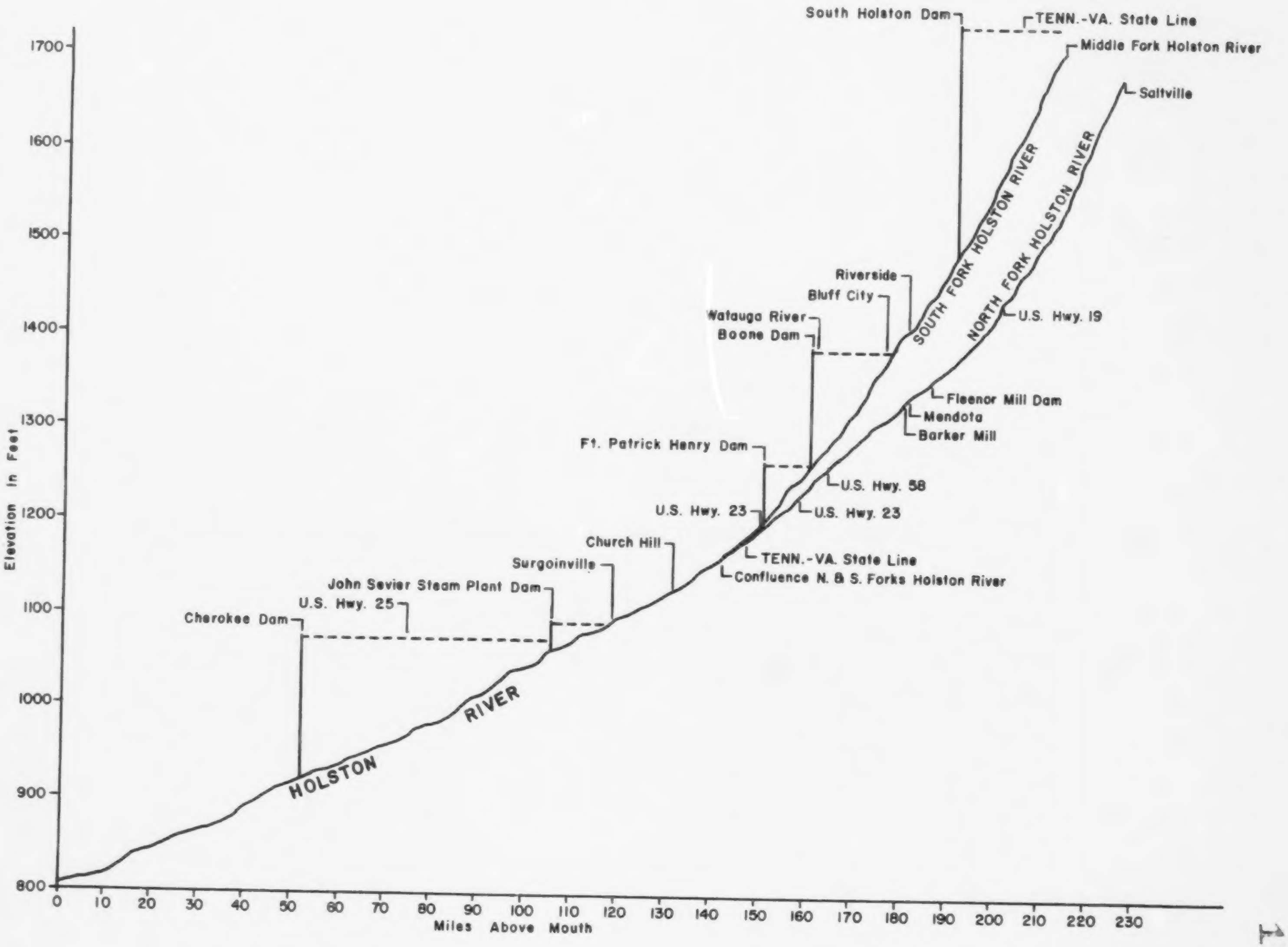

South Holston Dam
TENN.-VA. State Line
Middle Fork Holston River
Saltville
SOUTH FORK HOLSTON RIVER
NORTH FORK HOLSTON RIVER
U.S. Hwy. 19
Riverside
Bluff City
Watauga River
Boone Dam
Fleenor Mill Dam
Mendota
Barker Mill
Ft. Patrick Henry Dam
U.S. Hwy. 58
U.S. Hwy. 23
U.S. Hwy. 23
TENN.-VA. State Line
Confluence N. & S. Forks Holston River
Church Hill
Surgoinville
John Sevier Steam Plant Dam
U.S. Hwy. 25
Cherokee Dam
HOLSTON
RIVER
Elevation In Feet
1700
1600
1500
1400
1300
1200
1100
1000
900
800
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
Miles Above Mouth

FIGURE 3.1

LOCATION OF MAJOR INDUSTRIAL AND MUNICIPAL DISCHARGERS

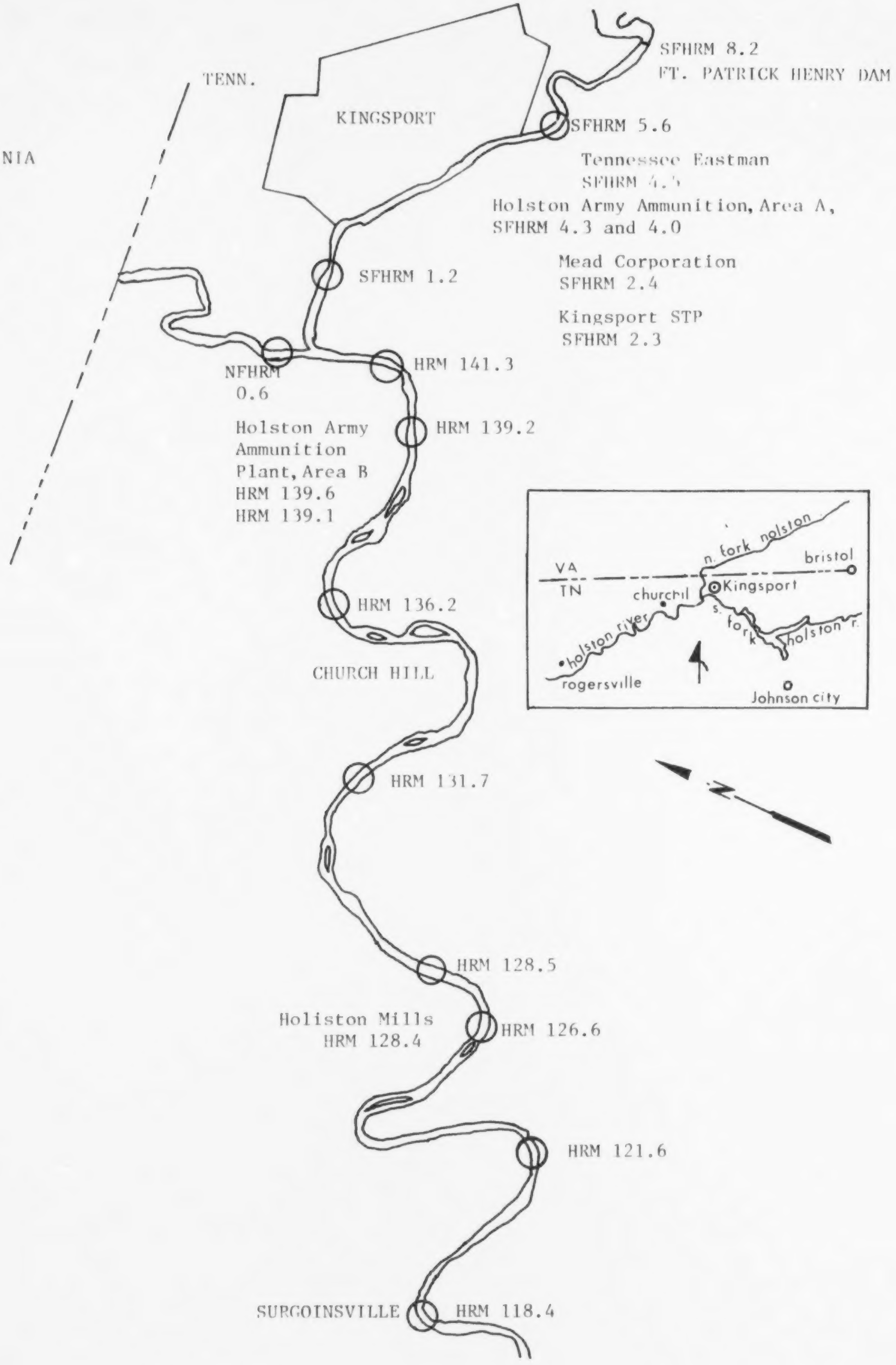

SFHRM 8.2
FT. PATRICK HENRY DAM
TENN.
KINGSPORT
VIRGINIA
SFHRM 5.6
Tennessee Eastman
SFHRM 4.5
Holston Army Ammunition, Area A,
SFHRM 4.3 and 4.0
SFHRM 1.2
Mead Corporation
SFHRM 2.4
Kingsport STP
SFHRM 2.3
NFHRM
0.6
HRM 141.3
Holston Army
Ammunition
Plant, Area B
HRM 139.6
HRM 139.1
HRM 139.2
HRM 136.2
CHURCH HILL
HRM 131.7
HRM 128.5
Holiston Mills
HRM 128.4
HRM 126.6
HRM 121.6
SURGOINSVILLE
HRM 118.4
N
VA
TN
n. fork holston
bristol
Kingsport
churchil
holston river
s. fork
holston r.
rogersville
Johnson city

FIGURE 5.2-1

AVERAGE BOD_5, TOTAL NITROGEN AND TOTAL PHOSPHORUS,
HOLSTON RIVER, JULY 1977

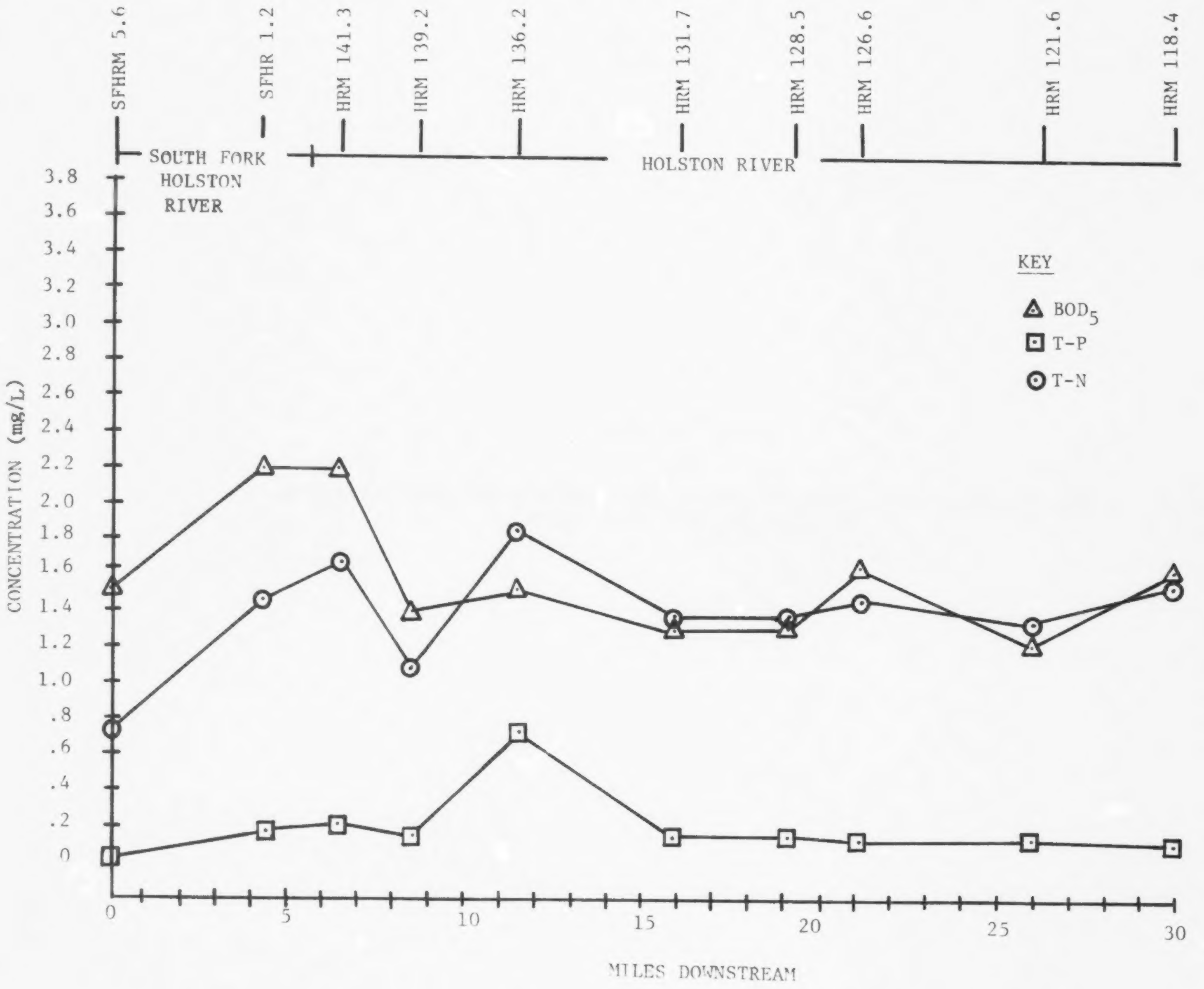

SFHRM 5.6
SFHR 1.2
HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 128.5
HRM 126.6
HRM 121.6
HRM 118.4
SOUTH FORK
HOLSTON
RIVER
HOLSTON RIVER
KEY
△ BOD_5
□ T-P
⊙ T-N
CONCENTRATION (mg/L)
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
0
5
10
15
20
25
30
MILES DOWNSTREAM

FIGURE 5.2-2

AVERAGE TOTAL KJELDAHL, AMMONIA AND NITRITE-NITRATE NITROGEN
HOLSTON RIVER, JULY 1977

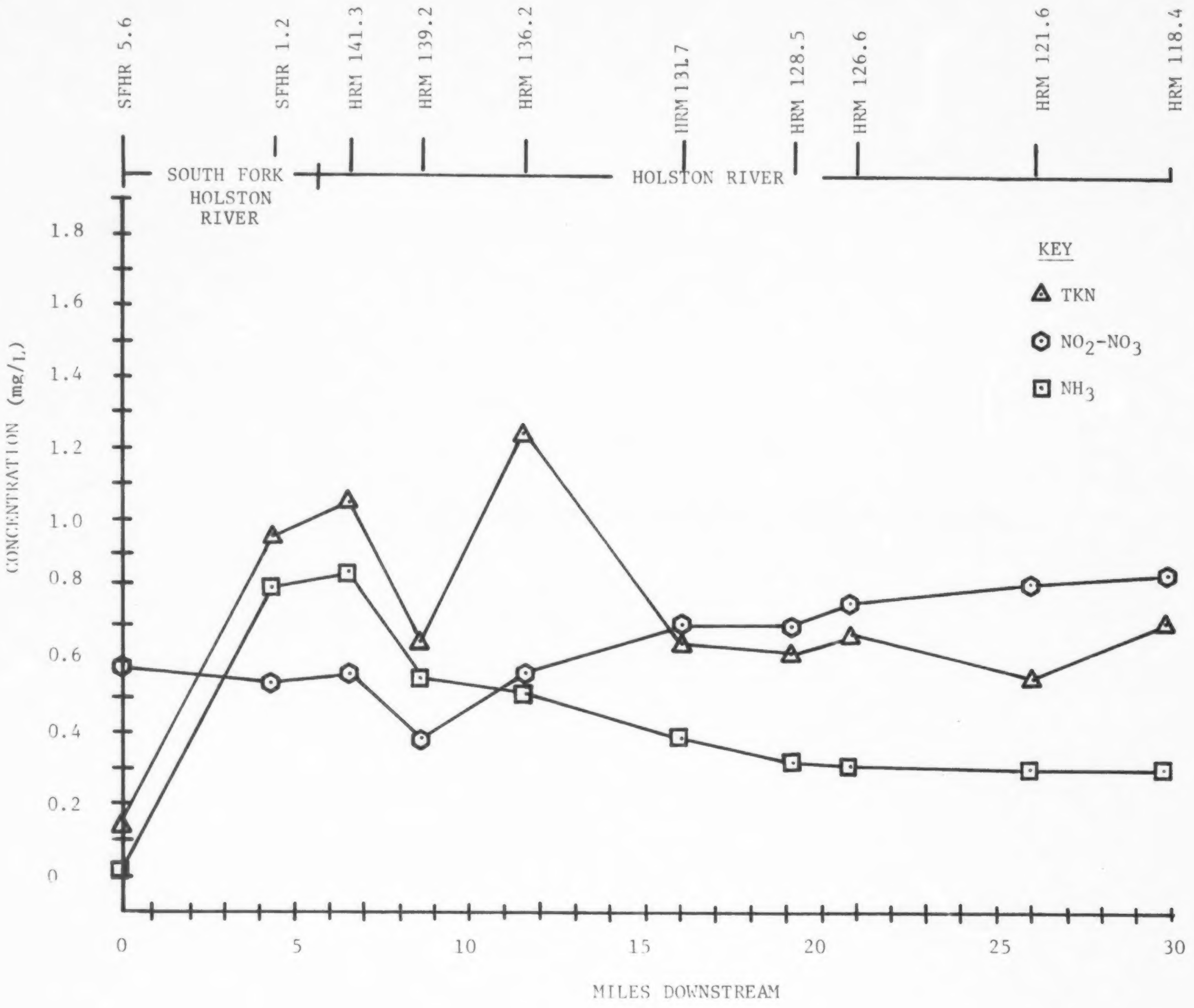

SFHR 5.6
SFHR 1.2
HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 128.5
HRM 126.6
HRM 121.6
HRM 118.4
SOUTH FORK HOLSTON RIVER
HOLSTON RIVER
KEY
TKN
NO_2-NO_3
NH_3
CONCENTRATION (mg/L)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
MILES DOWNSTREAM

FIGURE 5.2-3

DISSOLVED OYXGEN. HOLSTON RIVER, JULY, 1977

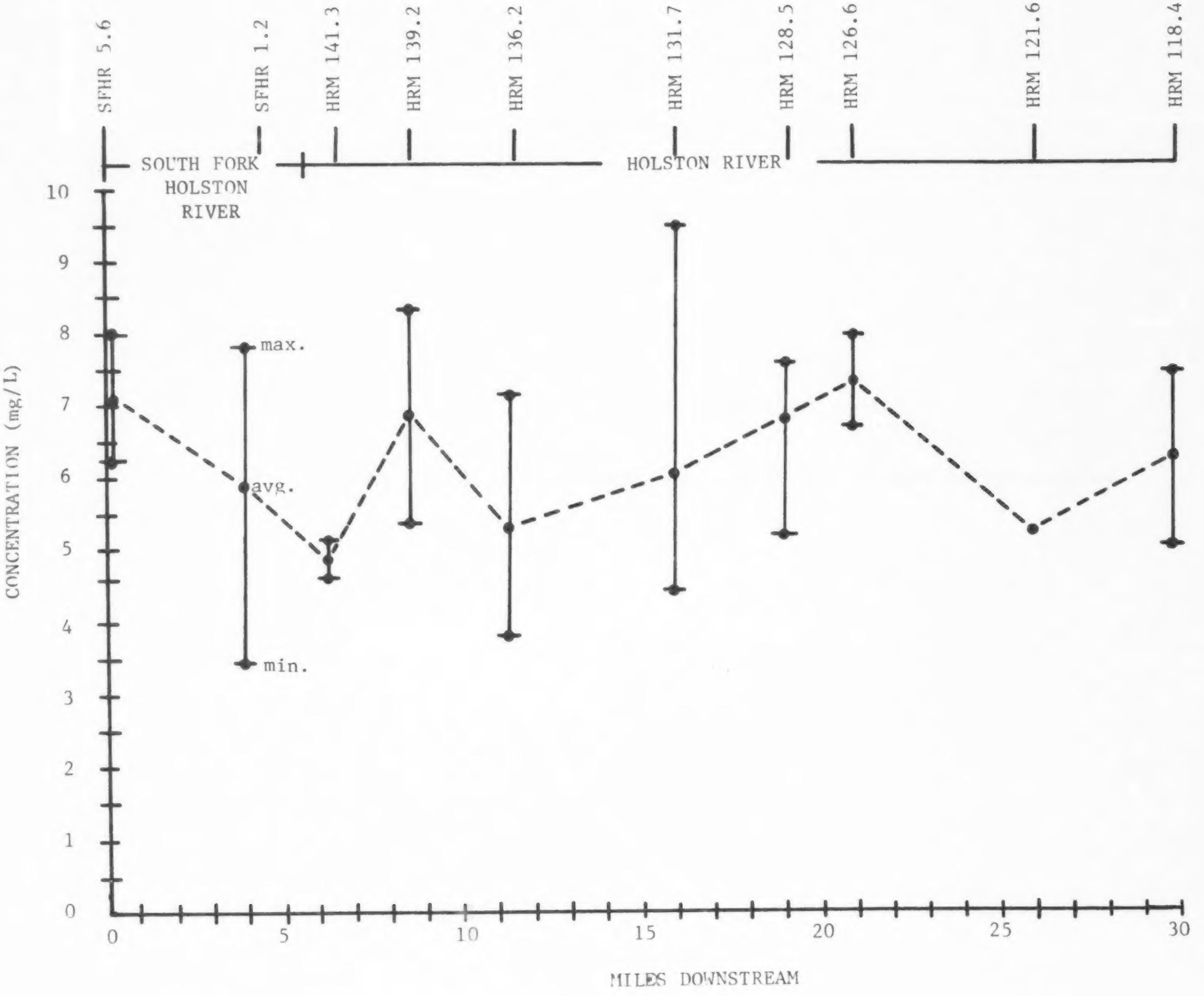

SFHR 5.6
SFHR 1.2
HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 128.5
HRM 126.6
HRM 121.6
HRM 118.4
SOUTH FORK HOLSTON RIVER
HOLSTON RIVER
max.
avg.
min.
CONCENTRATION (mg/L)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
MILES DOWNSTREAM

FIGURE 5.2-4

TEMPERATURE AND pH PROFILE. HOLSTON RIVER, JULY, 1977

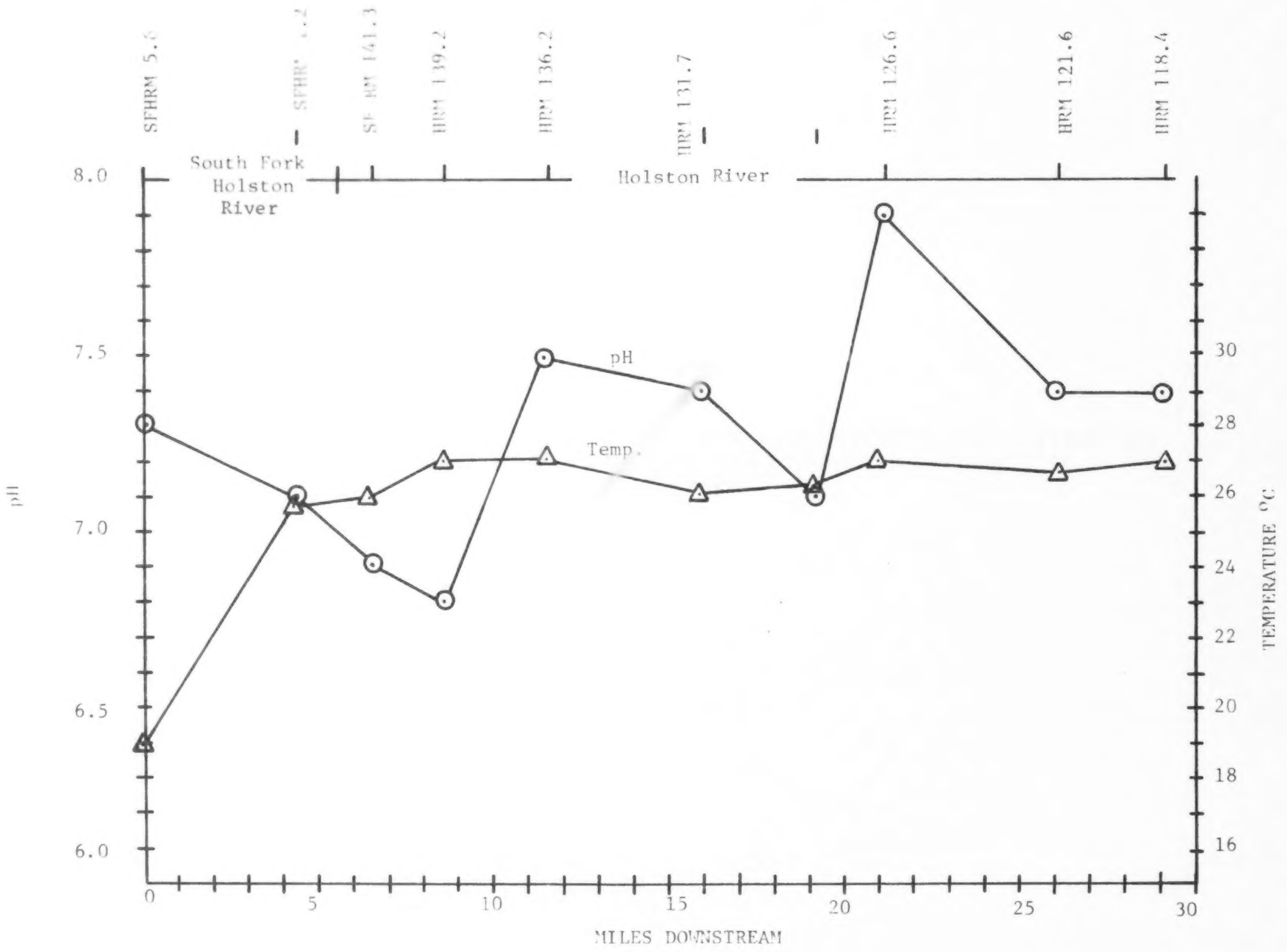
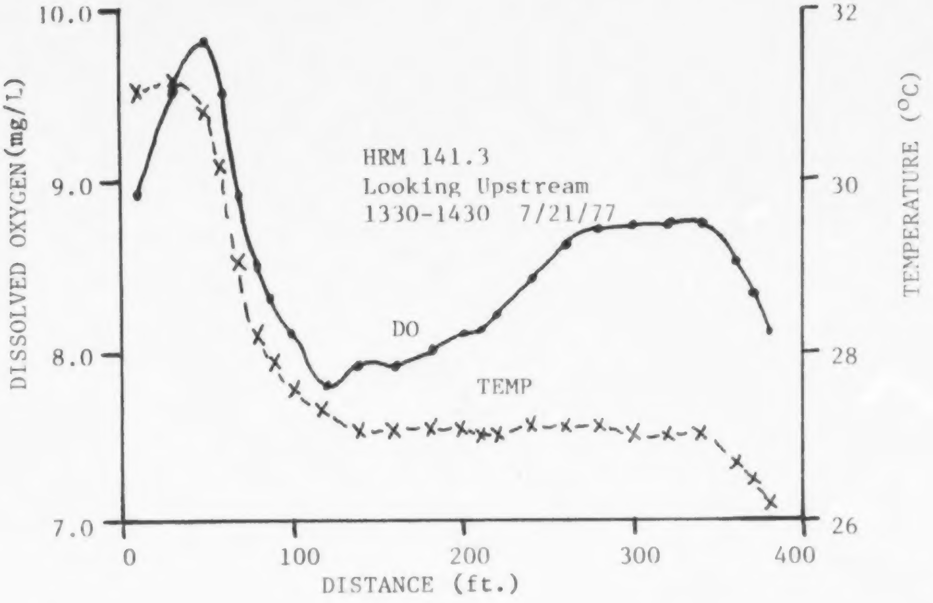

SFHRM 5.6
SFHRM .2
SF HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 126.6
HRM 121.6
HRM 118.4
South Fork Holston River
Holston River
pH
Temp.
8.0
7.5
7.0
6.5
6.0
30
28
26
24
22
20
18
16
0
5
10
15
20
25
30
MILES DOWNSTREAM
TEMPERATURE °C

FIGURE 5.2-5

MID DEPTH X-SECTION OF TEMPERATURE AND DISSOLVED OXYGEN DOWNSTREAM
OF CONFLUENCE OF NORTH AND SOUTH FORKS. HOLSTON RIVER.
JULY 1977


HRM 141.3
Looking Upstream
1330-1430 7/21/77
DO
TEMP
DISSOLVED OXYGEN (mg/L)
10.0
9.0
8.0
7.0
TEMPERATURE (°C)
32
30
28
26
0
100
200
300
400
DISTANCE (ft.)

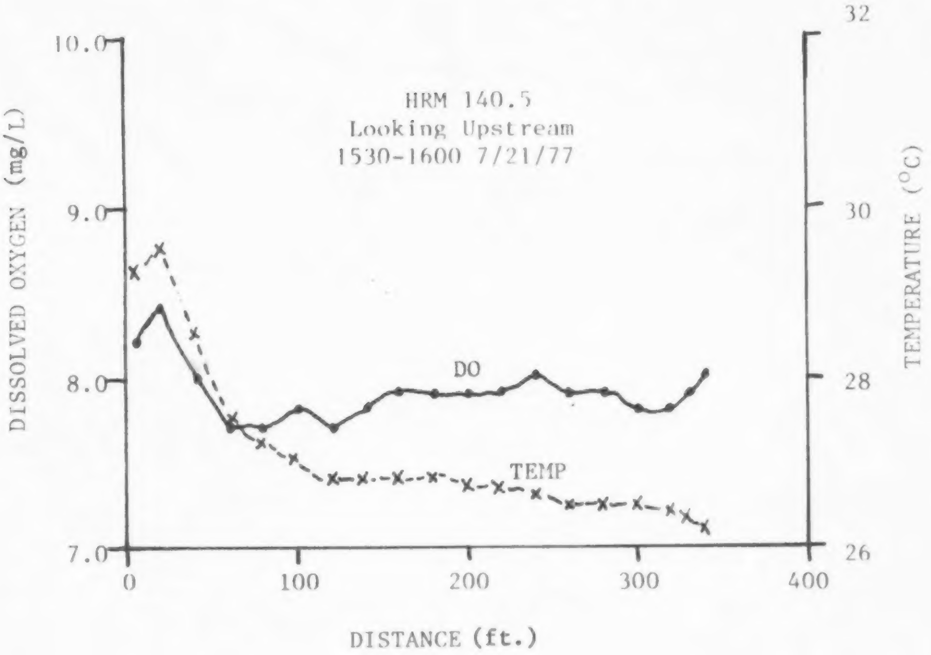

HRM 140.5
Looking Upstream
1530-1600 7/21/77
DO
TEMP
DISSOLVED OXYGEN (mg/L)
10.0
9.0
8.0
7.0
TEMPERATURE (°C)
32
30
28
26
0
100
200
300
400
DISTANCE (ft.)

FIGURE 5.2-6

BOD_5. HOLSTON RIVER. JULY, 1977

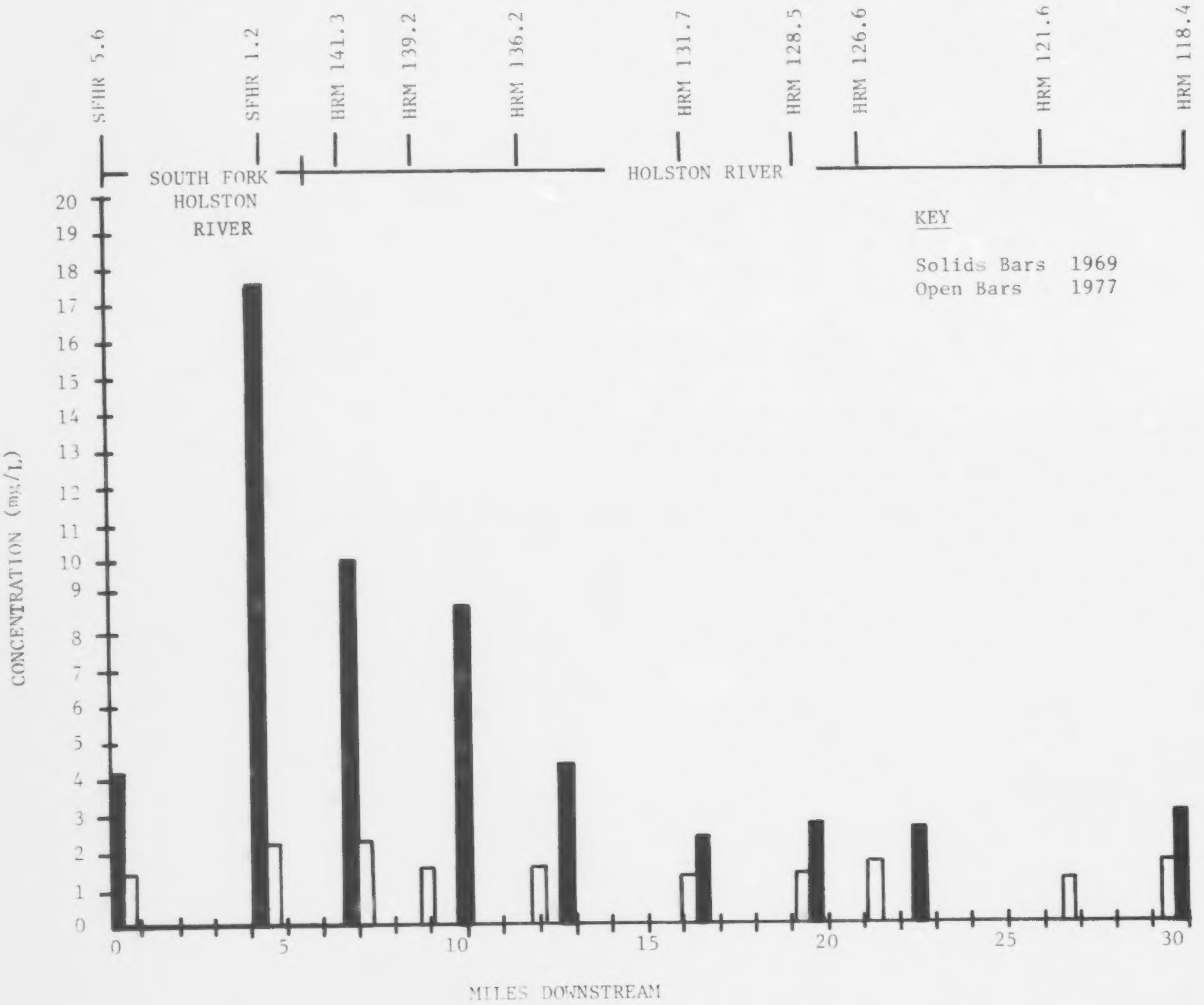

SFHR 5.6
SFHR 1.2
HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 128.5
HRM 126.6
HRM 121.6
HRM 118.4
SOUTH FORK
HOLSTON
RIVER
HOLSTON RIVER
KEY
Solids Bars 1969
Open Bars 1977
CONCENTRATION (mg/L)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
MILES DOWNSTREAM

FIGURE 5.2-7

TOTAL NITROGEN. HOLSTON RIVER JULY, 1977

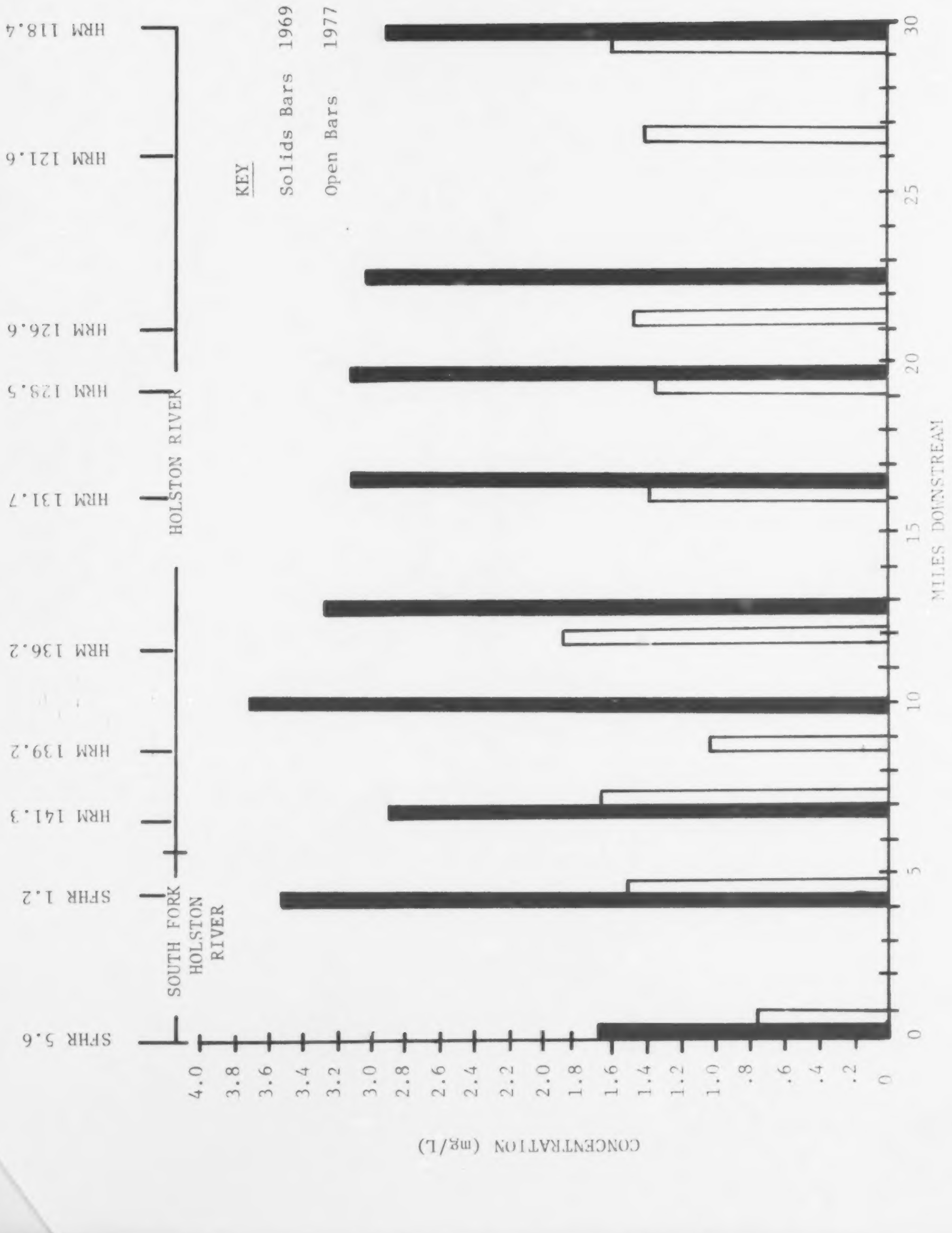

KEY
Solids Bars 1969
Open Bars 1977
SFHR 5.6
SFHR 1.2
HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 128.5
HRM 126.6
HRM 121.6
HRM 118.4
SOUTH FORK HOLSTON RIVER
HOLSTON RIVER
MILES DOWNSTREAM
0
5
10
15
20
25
30
CONCENTRATION (mg/L)
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0

FIGURE 5.2-8

AVERAGE DISSOLVED OXYGEN. HOLSTON RIVER. JULY, 1977

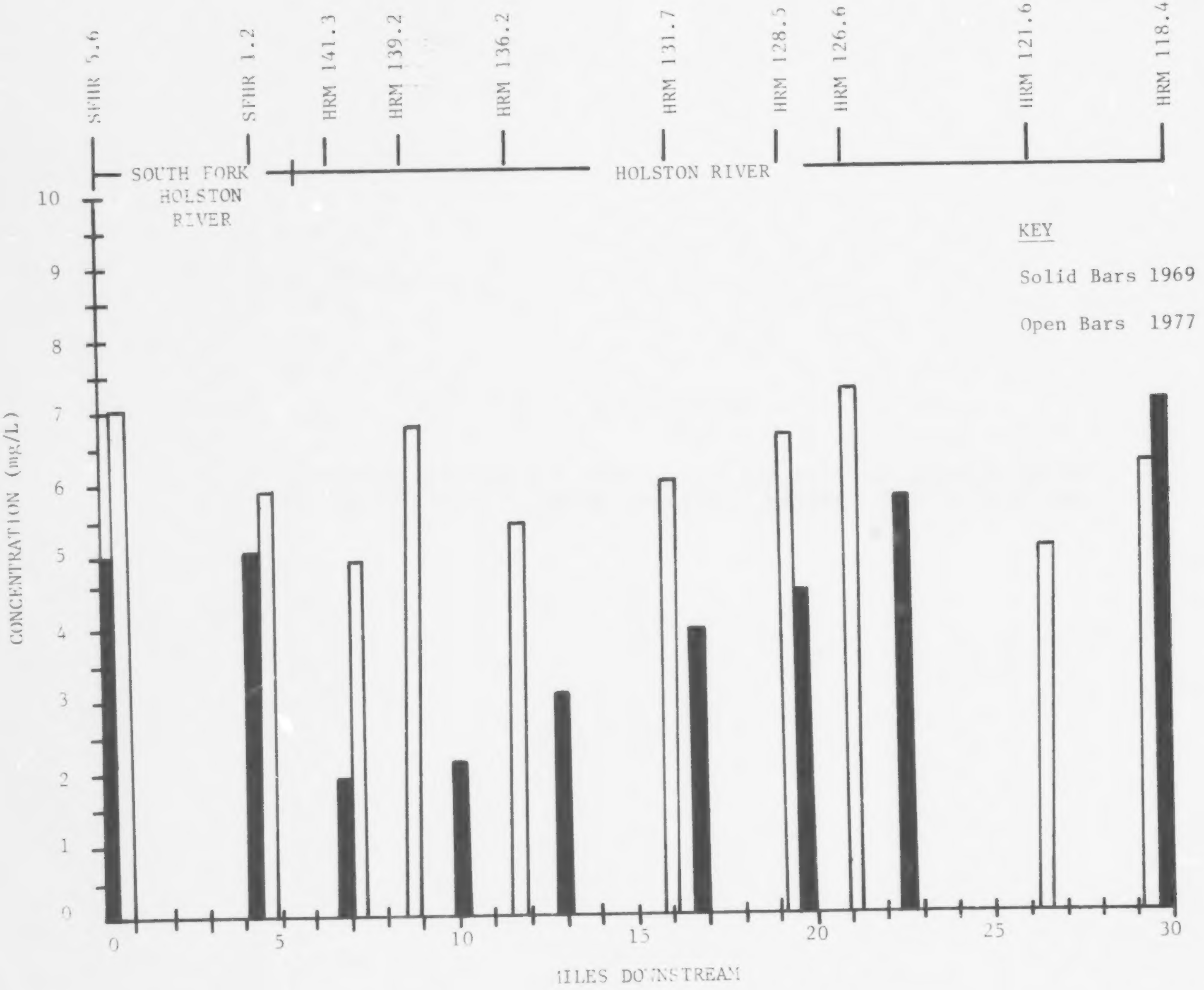

SFHR 5.6
SFHR 1.2
HRM 141.3
HRM 139.2
HRM 136.2
HRM 131.7
HRM 128.5
HRM 126.6
HRM 121.6
HRM 118.4
SOUTH FORK HOLSTON RIVER
HOLSTON RIVER
KEY
Solid Bars 1969
Open Bars 1977
CONCENTRATION (mg/L)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
MILES DOWNSTREAM

FIGURE 5.3-1

TOTAL NUMBERS OF TAXA COLLECTED FROM ARTIFICIAL SUBSTRATES AND QUALITATIVE SAMPLES. HOLSTON RIVER. JULY-AUGUST, 1977

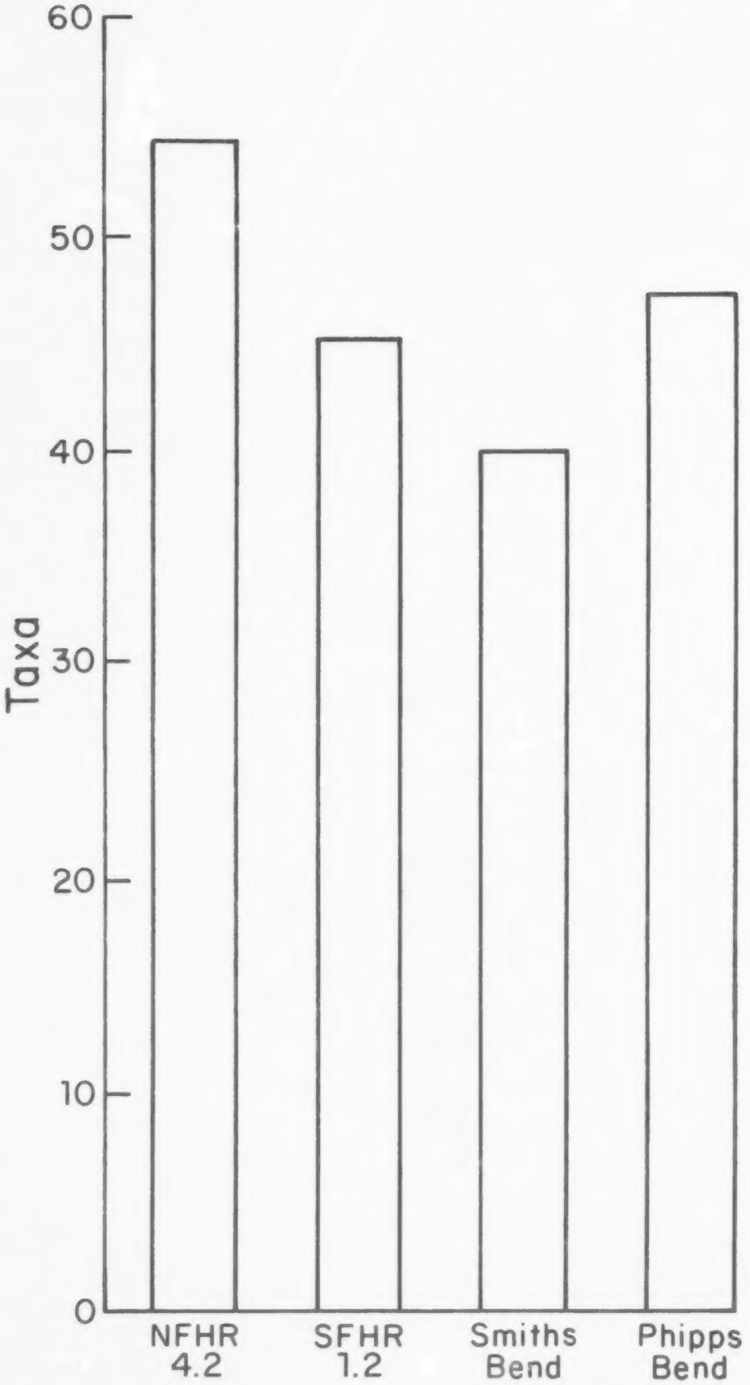

60
50
40
30
20
10
0
Taxa
NFHR 4.2
SFHR 1.2
Smiths Bend
Phipps Bend

FIGURE 5.3-2

AVERAGE NUMBER OF INDIVIDUALS AND TOTAL TAXA COLLECTED FROM
ARTIFICIAL SUBSTRATES. HOLSTON RIVER.
JULY-AUGUST, 1977

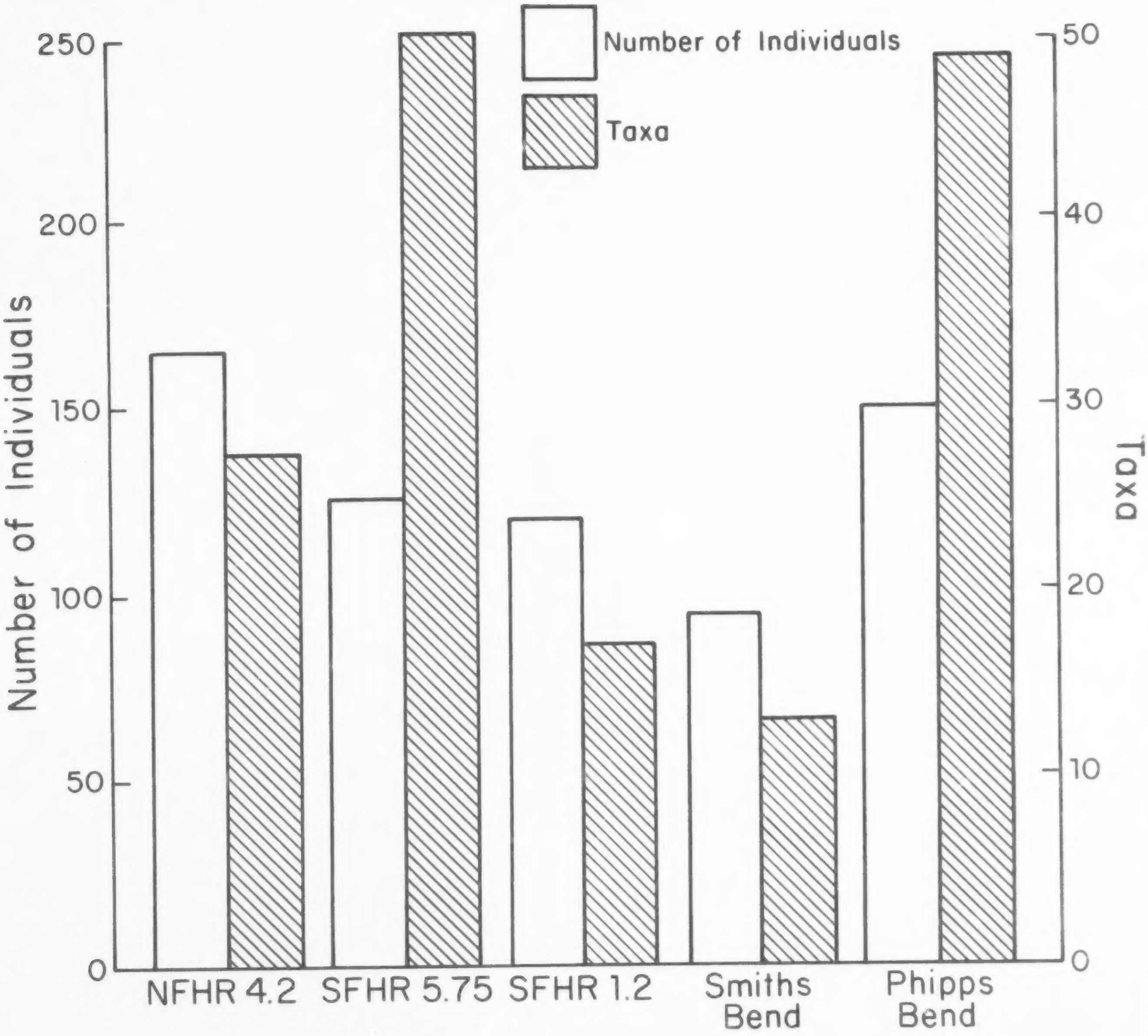
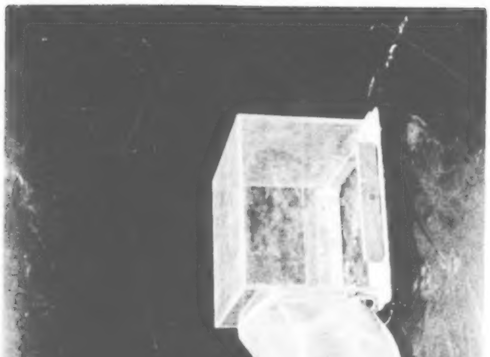

Number of Individuals
Taxa
250
200
150
100
50
0
Number of Individuals
50
40
30
20
10
0
Taxa
NFHR 4.2
SFHR 5.75
SFHR 1.2
Smiths Bend
Phipps Bend

FIGURE 5.4-2

P AND D EPIBENTHIC SAMPLER



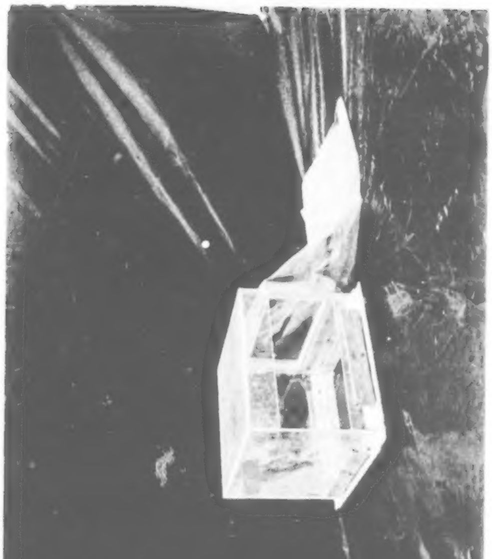
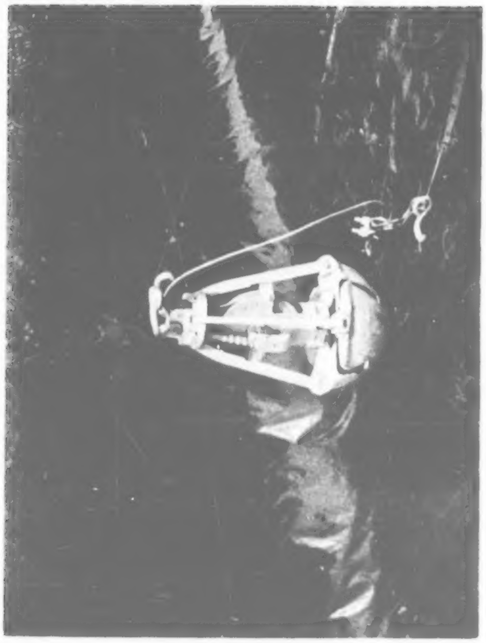


FIGURE 5.4-1

ORANGE PEEL SAMPLER



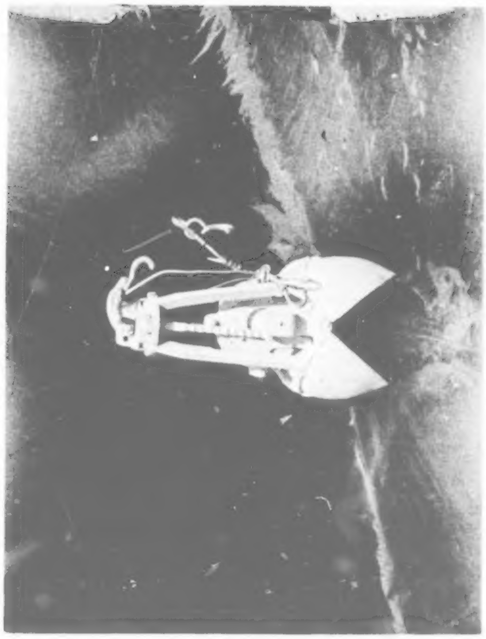


FIGURE 5.5-1

AVERAGE NITROGEN CONCENTRATIONS IN THE HOLSTON RIVER
DURING STEADY-STATE CONDITIONS. JULY, 1977

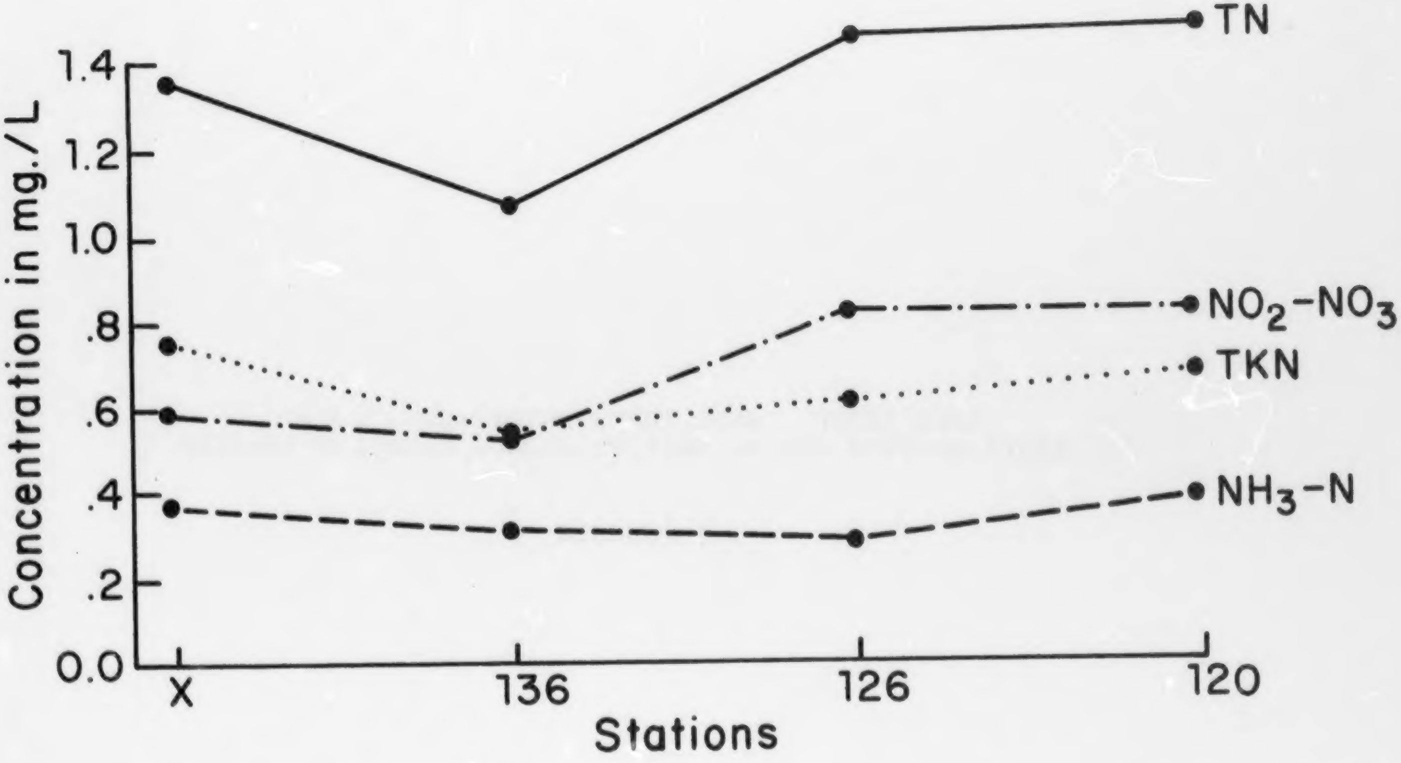

Concentration in mg./L
1.4
1.2
1.0
.8
.6
.4
.2
0.0
X
136
126
120
Stations
TN
NO_2-NO_3
TKN
NH_3-N

FIGURE 5.5-2

AVERAGE NITROGEN CONCENTRATIONS IN THE HOLSTON RIVER
DURING FLUCTUATING CONDITIONS. JULY, 1977

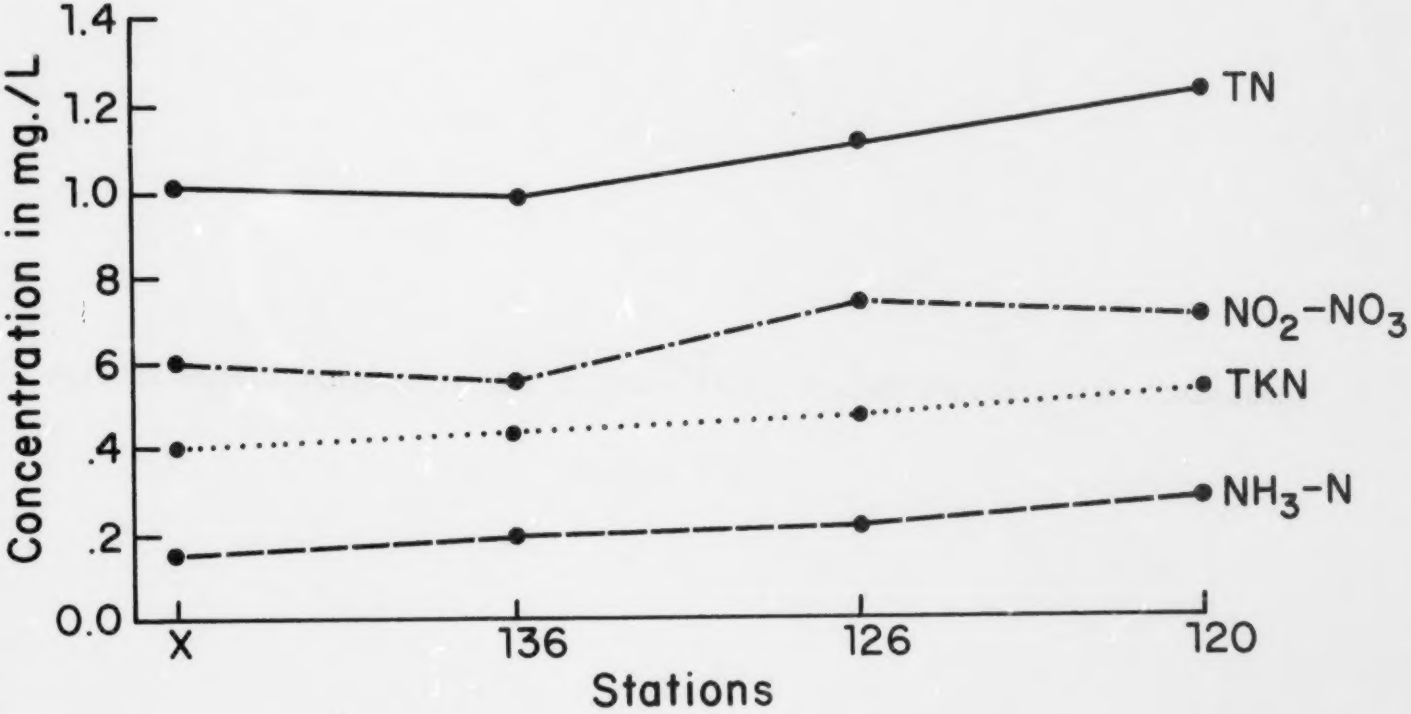

Concentration in mg./L
1.4
1.2
1.0
8
6
.4
.2
0.0
X
136
126
120
Stations
TN
NO_2-NO_3
TKN
NH_3-N

FIGURE 5.5-3

AVERAGE HOURLY LOADING IN THE HOLSTON RIVER DURING STEADY-STATE CONDITIONS.
JULY, 1977

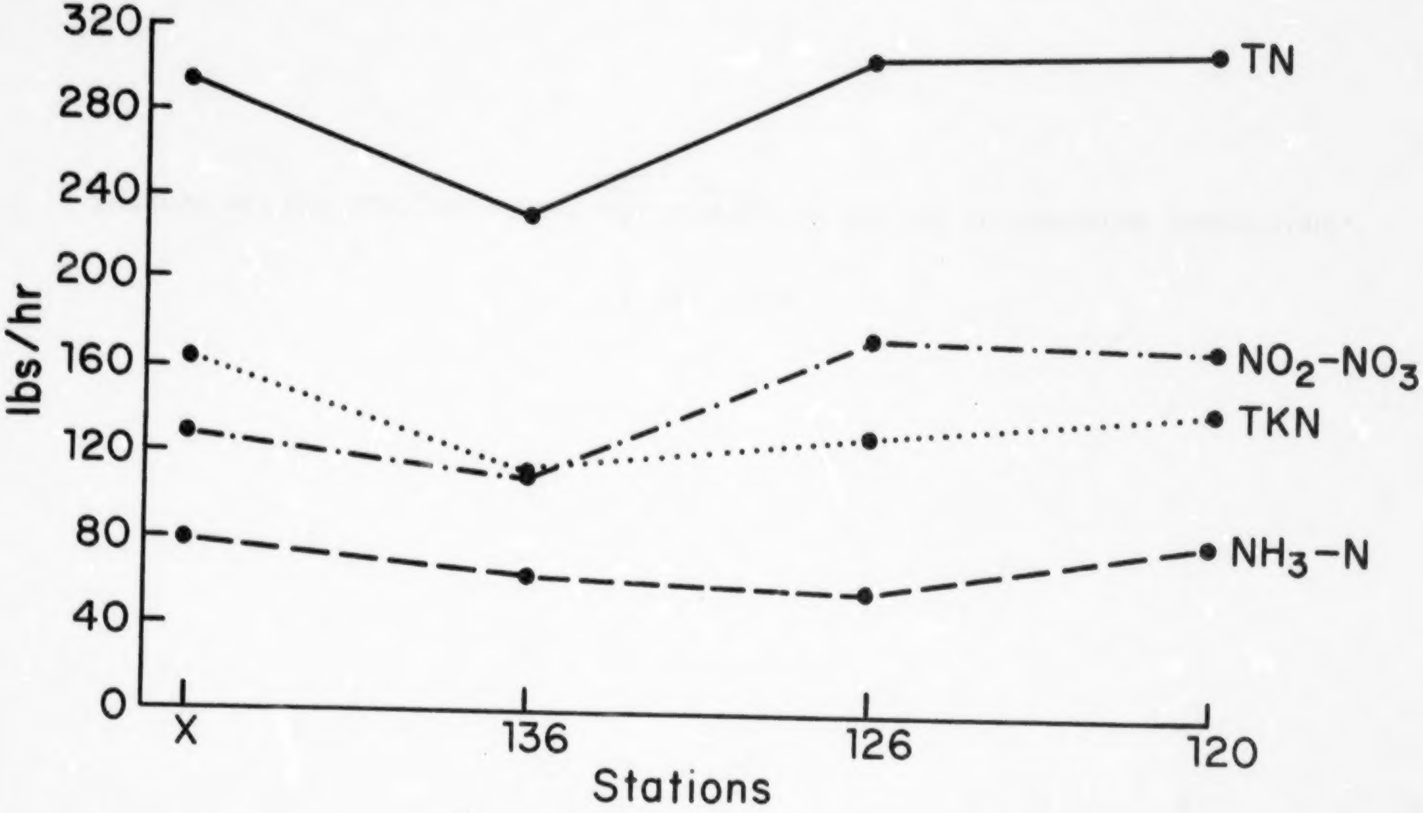

320
280
240
200
160
120
80
40
0
lbs/hr
X
136
126
120
Stations
TN
NO_2-NO_3
TKN
NH_3-N

FIGURE 5.5-4

AVERAGE HOURLY LOADING IN THE HOLSTON RIVER DURING FLUCTUATING CONDITIONS.
JULY, 1977

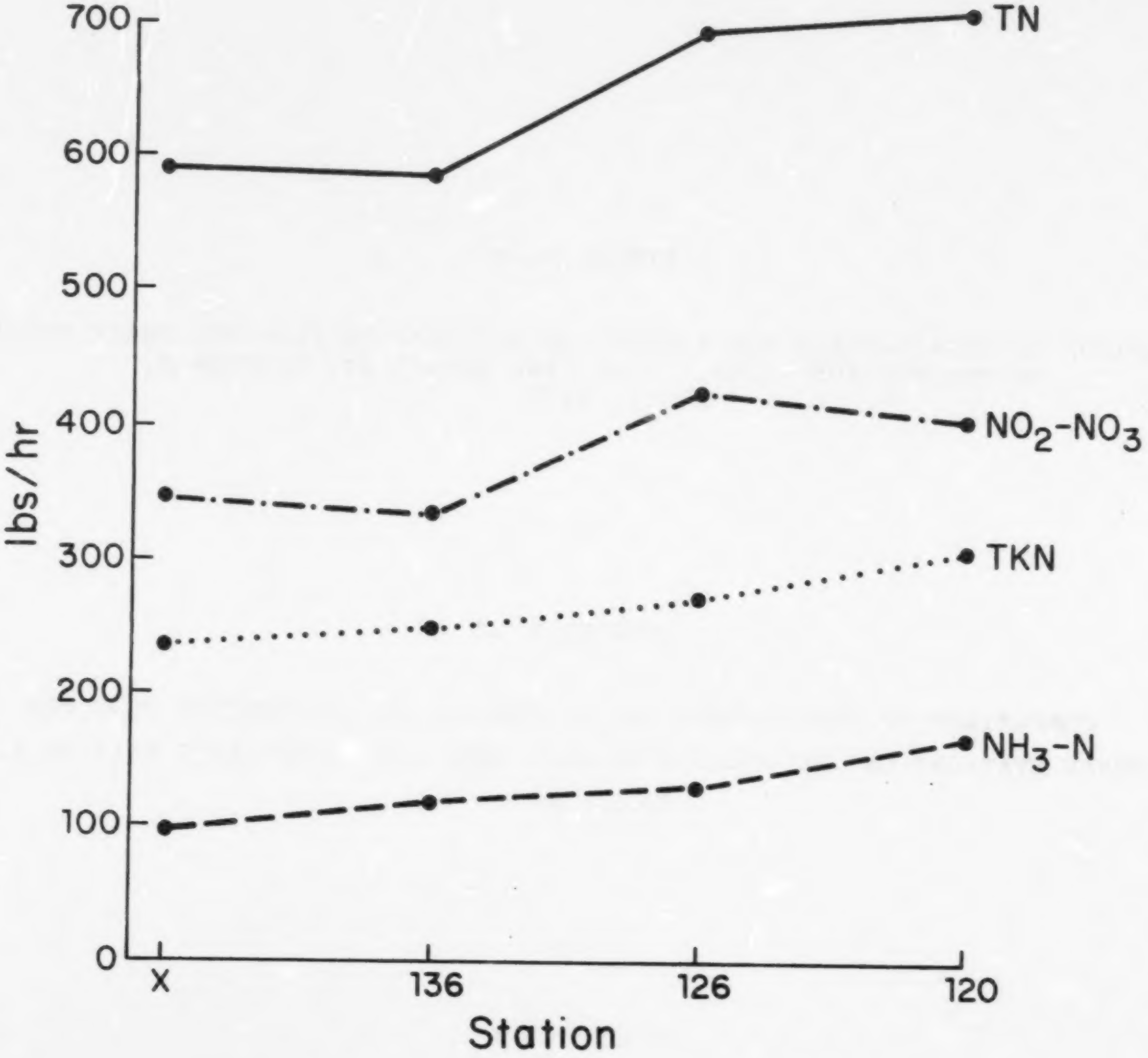

700
600
500
400
300
200
100
0
lbs/hr
TN
NO$_2$-NO$_3$
TKN
NH$_3$-N
X
136
126
120
Station

FIGURE 5.5-5

COMPARISON OF STEADY-STATE TOTAL NITROGEN LOADING VS FLUCTUATING FLOW FOR THREE STATIONS ON THE HOLSTON RIVER. ZERO LINE REPRESENTS STATION X.
JULY, 1977

FIGURE 5.5-6

COMPARISON OF STEADY-STATE TKN LOADING VS FLUCTUATING FLOW FOR THREE STATIONS ON THE HOLSTON RIVER. ZERO LINE REPRESENTS STATION X.
JULY, 1977

FIGURE 5.5-7

COMPARISON OF STEADY-STATE NH_3-N LOADING VS FLUCTUATING FLOW FOR THREE STATIONS ON THE HOLSTON RIVER. ZERO LINE REPRESENTS STATION X.
JULY, 1977

FIGURE 5.5-8

COMPARISON OF STEADY-STATE NO_2-NO_3-N LOADING VS FLUCTUATING FLOW FOR THREE STATIONS ON THE HOLSTON RIVER. ZERO LINE REPRESENTS STATION X.
JULY, 1977

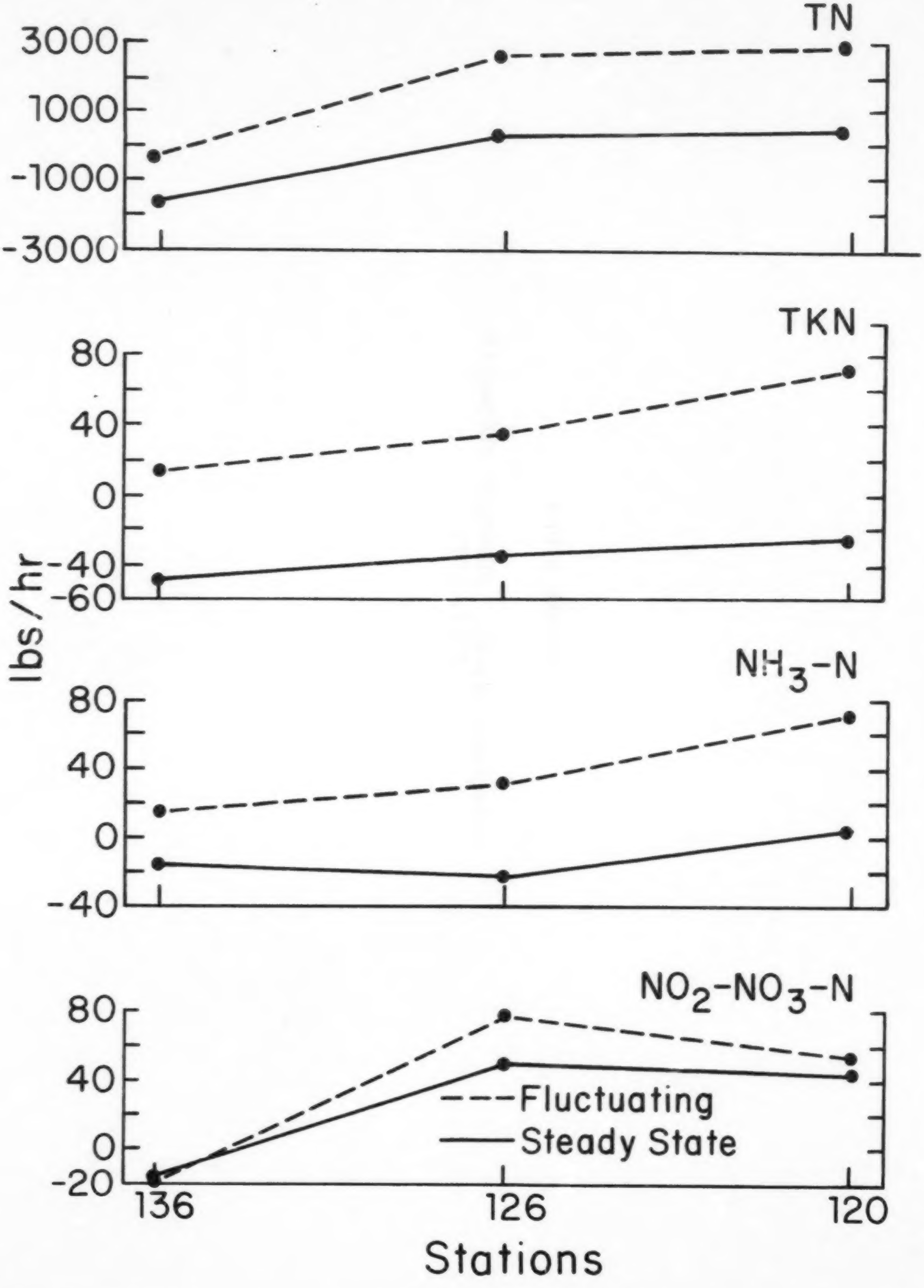
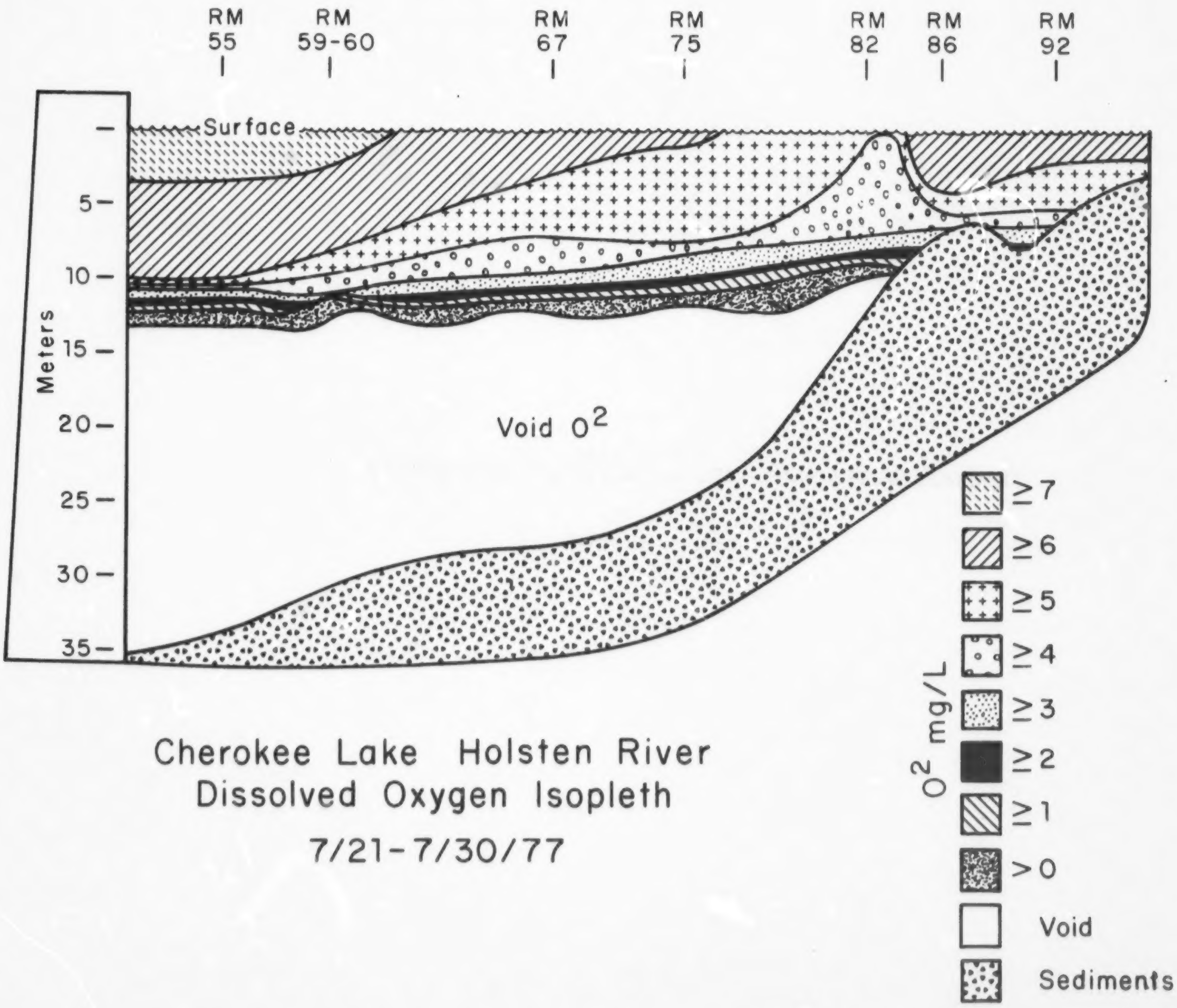

TN
3000
1000
-1000
-3000
TKN
80
40
0
-40
-60
lbs/hr
NH$_3$-N
80
40
0
-40
NO$_2$-NO$_3$-N
80
40
0
-20
Fluctuating
Steady State
136
126
120
Stations

FIGURE 5.10-1

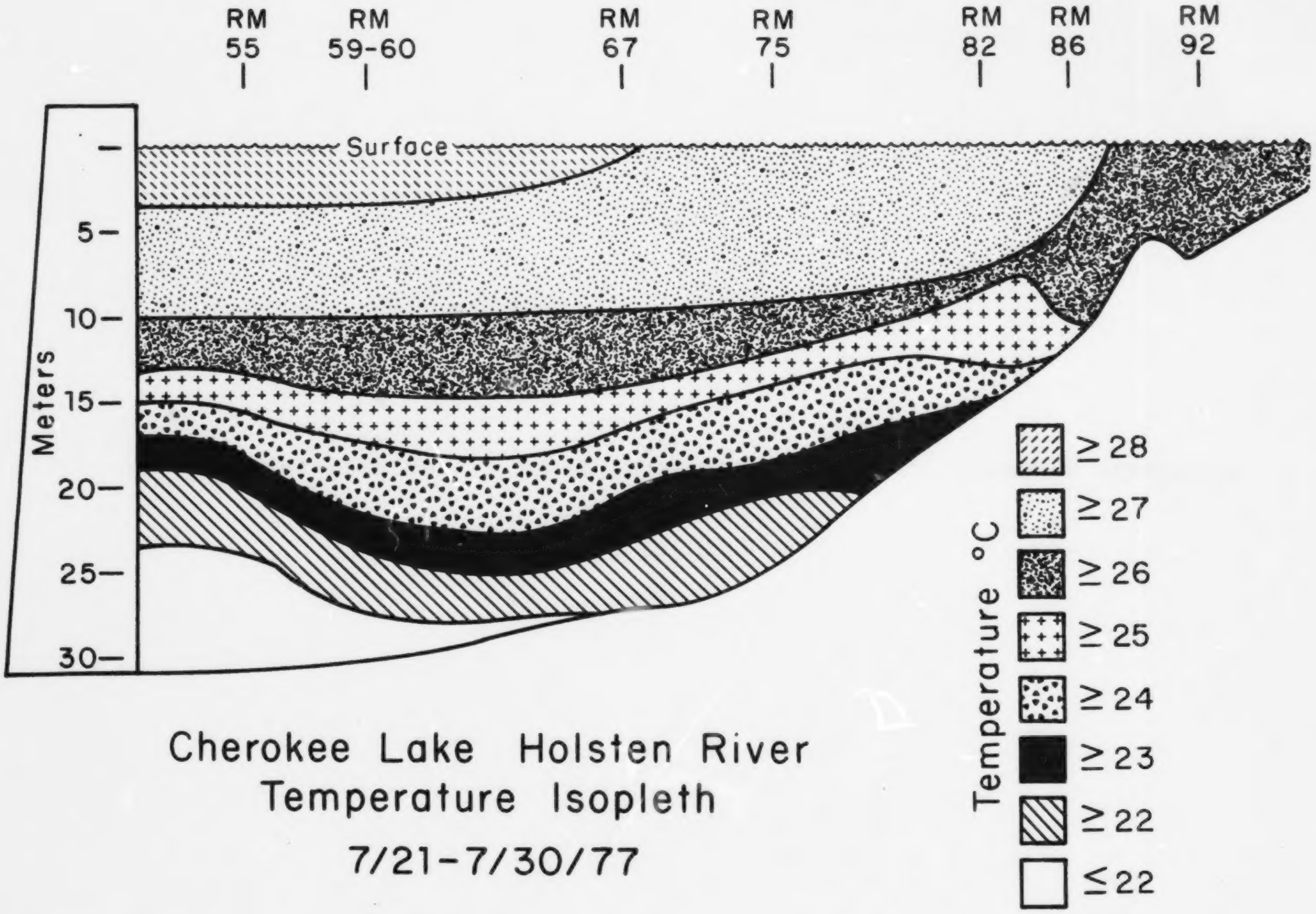
DISSOLVED OXYGEN. CHEROKEE RESERVOIR.
JULY, 1977



Cherokee Lake Holsten River
Dissolved Oxygen Isopleth
7/21-7/30/77

FIGURE 5.10-2

TEMPERATURE ISOPLETH IN °C. CHEROKEE RESERVOIR.
JULY, 1977



Cherokee Lake Holsten River
Temperature Isopleth
7/21-7/30/77

FIGURE 5.10-3

SECCHI DISK AND 1% LIGHT TRANSMISSION LEVELS. CHEROKEE RESERVOIR.
JULY, 1977

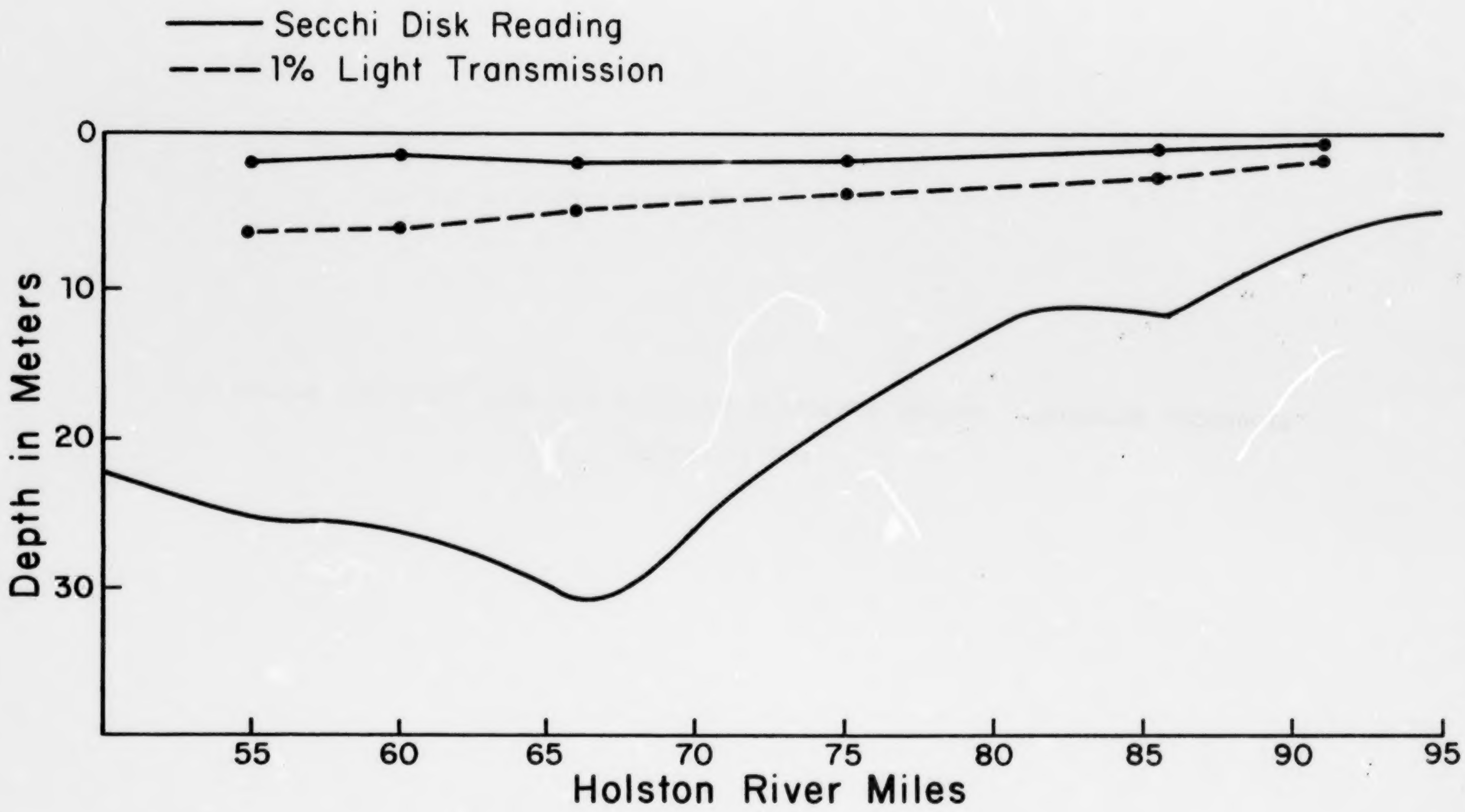
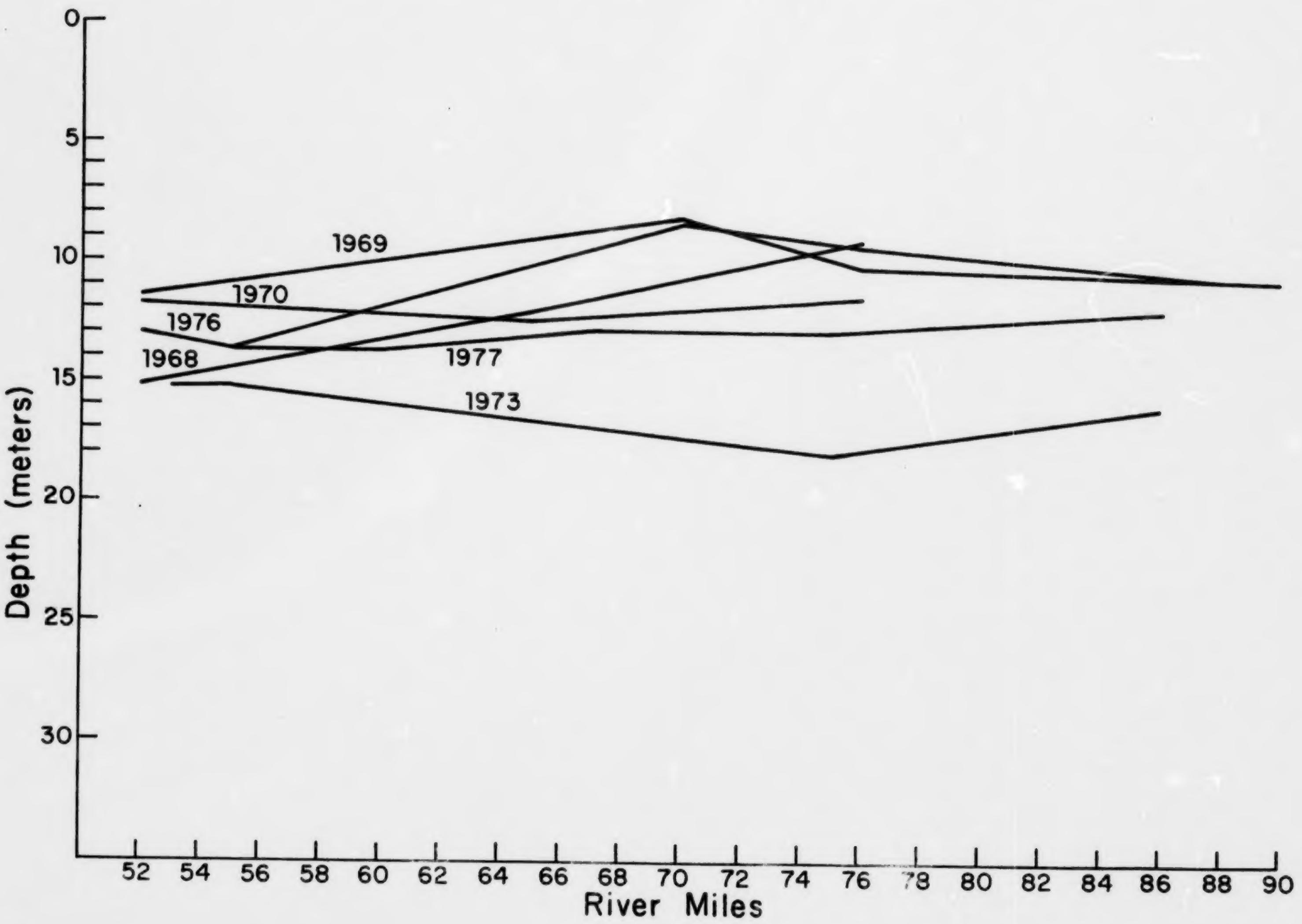

Secchi Disk Reading
1% Light Transmission
Depth in Meters
0
10
20
30
55
60
65
70
75
80
85
90
95
Holston River Miles

FIGURE 5.10-4

DEPTHS WITH LESS THAN 1.0 MG/LITER DISSOLVED OXYGEN. CHEROKEE RESERVOIR.



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